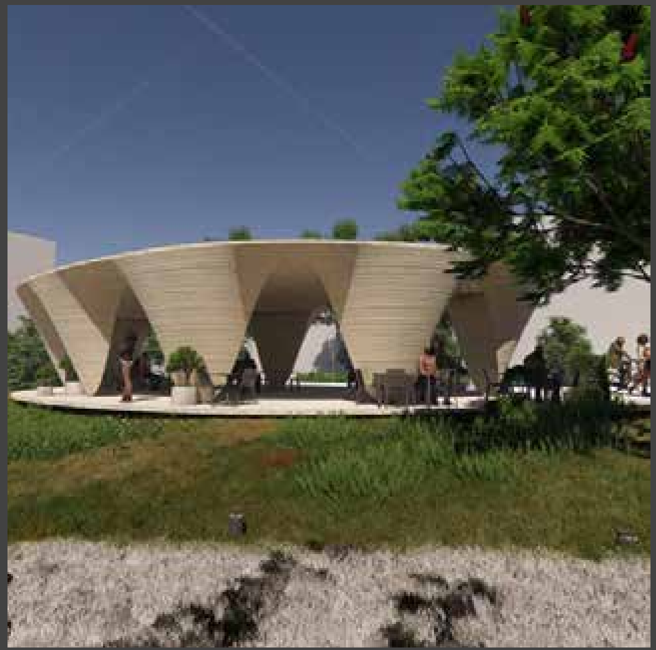
N3XTCON

3D PRINT CATALOG

04 JAN 2024

CONTENT

















01

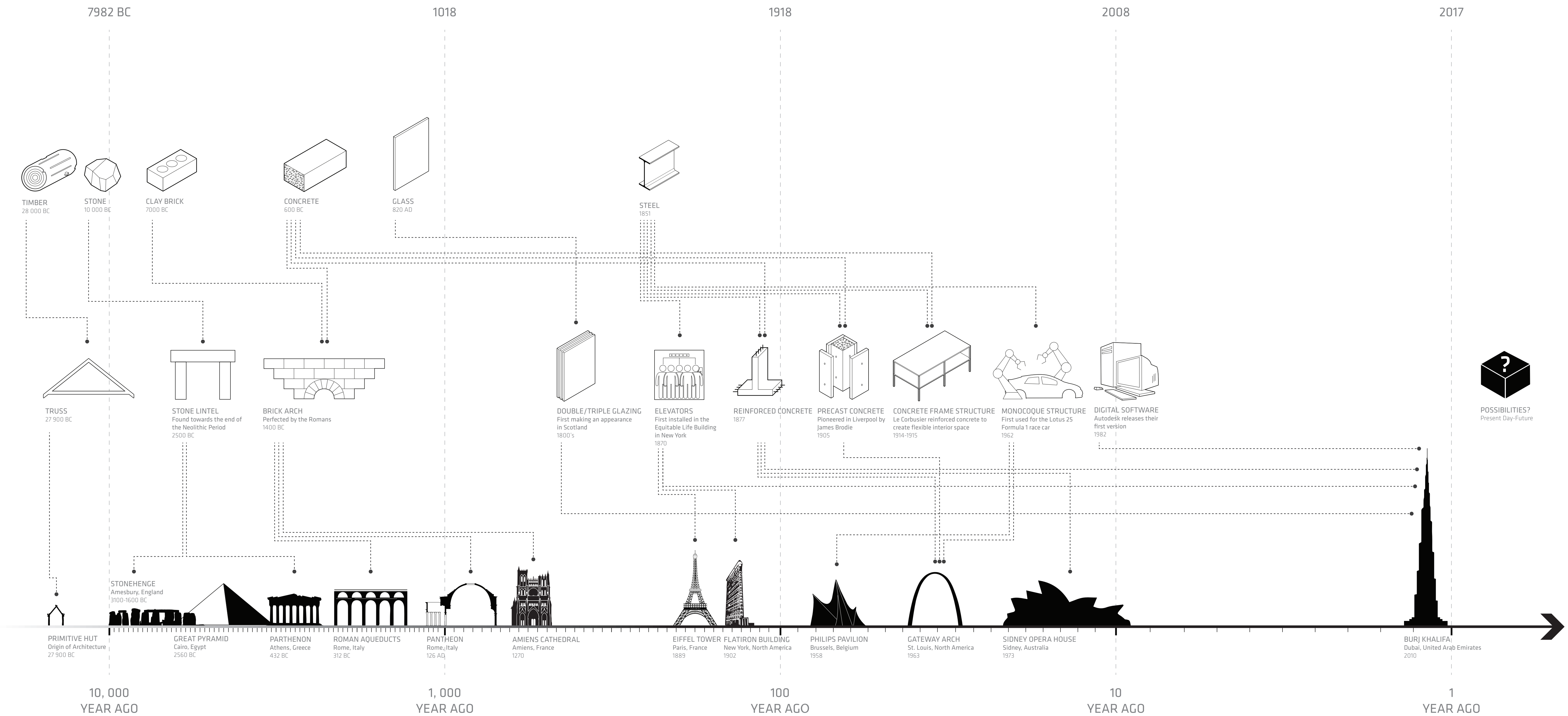
INTRODUCTION

N3XTCON - NEXT GENERATION 3D-PRINTED CONCRETE STRUCTURES

N3XTCON is a project funded by Innovation Fund Denmark to develop a solution that brings 3D Concrete Printing to an industrial scale. As such, we move from the current experimental/exploration phase (i.e. small-scale demo projects without reinforcement) to a real productivity-increasing solution based on reinforced concrete.

The N3XTCON industrial solution paves the way for digital fabrication of the next generation of custom-made concrete structures that offers significant material savings and new architectural opportunities – all of it at lower costs when compared to traditional construction. Our development relies on current state-of-the-art knowledge on 3DCP and creates new knowledge on, 3DCP simulation based on material- and print parameters, upscaling of materials from mortar to concrete and novel reinforcement strategies for 3DCP.

With every technology comes a revolution - often where application lags behind potential.


7982 BC
1018
1918
2008
2017
TIMBER
28 000 BC
STONE
10 000 BC
CLAY BRICK
7000 BC
CONCRETE
600 BC
GLASS
820 AD
STEEL
1851
TRUSS
27 900 BC
STONE LINTEL
Found towards the end of the Neolithic Period
2500 BC
BRICK ARCH
Perfected by the Romans
1400 BC
DOUBLE/TRIPLE GLAZING
First making an appearance in Scotland
1800's
ELEVATORS
First installed in the Equitable Life Building in New York
1870
REINFORCED CONCRETE
1877
PRECAST CONCRETE
Pioneered in Liverpool by James Brodie
1905
CONCRETE FRAME STRUCTURE
Le Corbusier reinforced concrete to create flexible interior space
1914-1915
MONOCOQUE STRUCTURE
First used for the Lotus 25 Formula 1 race car
1962
DIGITAL SOFTWARE
Autodesk releases their first version
1982
?
POSSIBILITIES?
Present Day-Future
STONEHENGE
Amesbury, England
3100-1600 BC
PRIMITIVE HUT
Origin of Architecture
27 900 BC
GREAT PYRAMID
Cairo, Egypt
2560 BC
PARTHENON
Athens, Greece
432 BC
ROMAN AQUEDUCTS
Rome, Italy
312 BC
PANTHEON
Rome, Italy
126 AD
AMIENS CATHEDRAL
Amiens, France
1270
EIFFEL TOWER
Paris, France
1889
FLATIRON BUILDING
New York, North America
1902
PHILIPS PAVILION
Brussels, Belgium
1958
GATEWAY ARCH
St. Louis, North America
1963
SIDNEY OPERA HOUSE
Sidney, Australia
1973
BURJ KHALIFA
Dubai, United Arab Emirates
2010
10, 000
YEAR AGO
1, 000
YEAR AGO
100
YEAR AGO
10
YEAR AGO
1
YEAR AGO

3D printing in construction was first explored in the 2000s, and it is now that we're seeing feasible applications arrive...


COBOD

Its advantages lie in reducing human labor while increasing precision and specificity.

In a market driven by economies of scale, where profit is only found in bulk...

...we are exploring a new modularity.

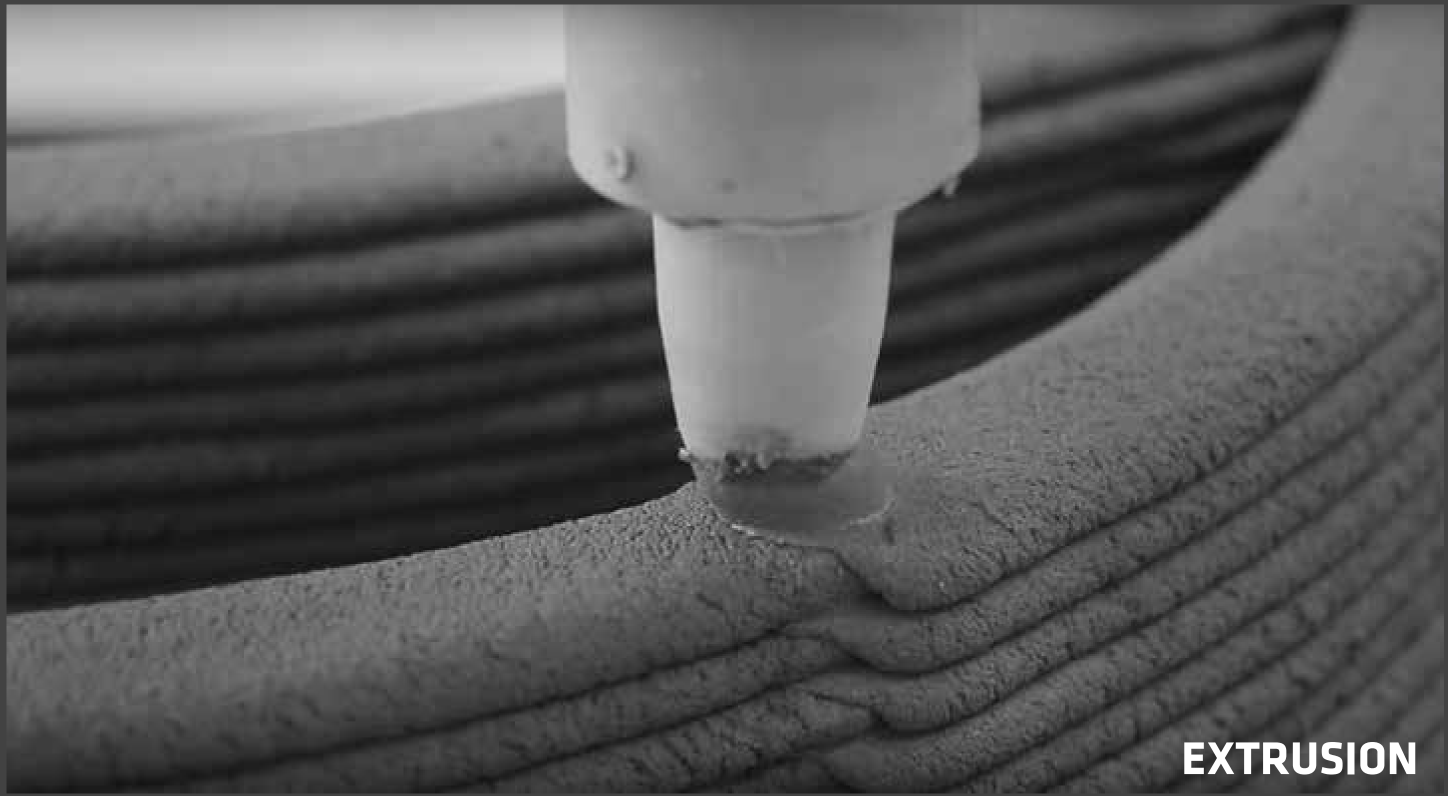
A bespoke kit of parts with the flexibilty to adapt to any condition.

3D printing allows us to focus on the individual and tailor for the specific again...

...and it allows for structural and functional optimization that would otherwise be economically nonviable.

02

PRINTING METHODS


EXTRUSION

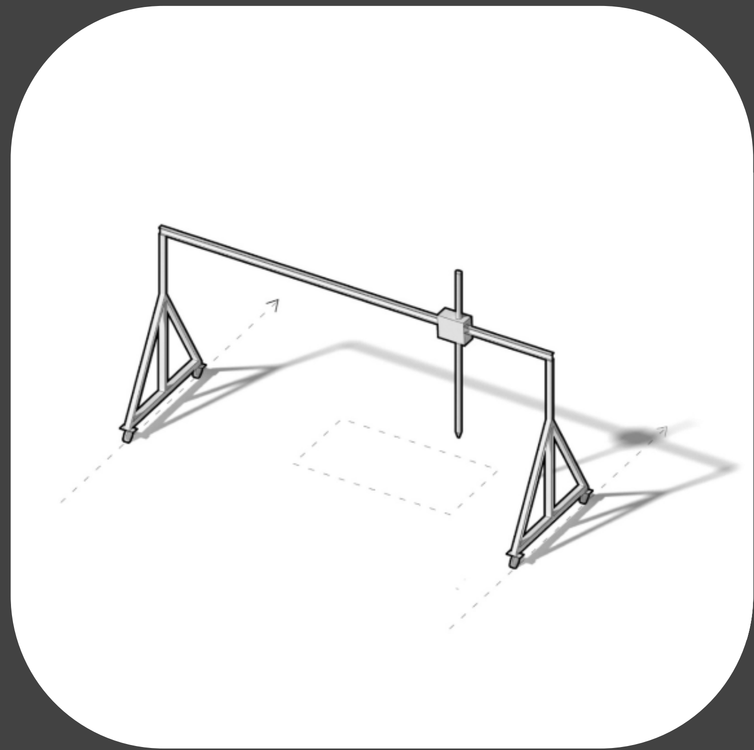

LAYER SINTERING


ROBOT ARM


GANTRY

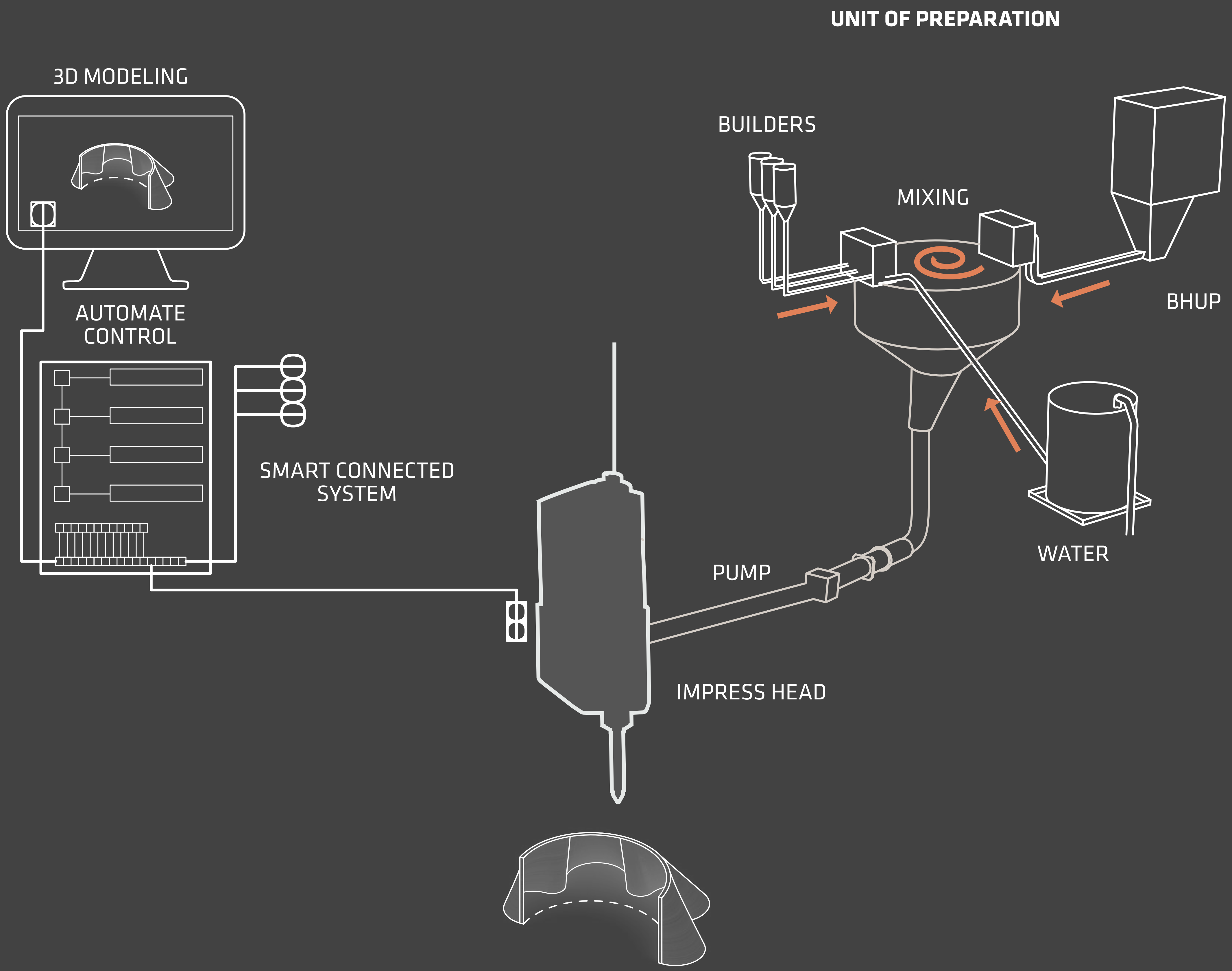
PRINTING SYSTEMS

SINGLE ROBOTIC
ARM PRINTER



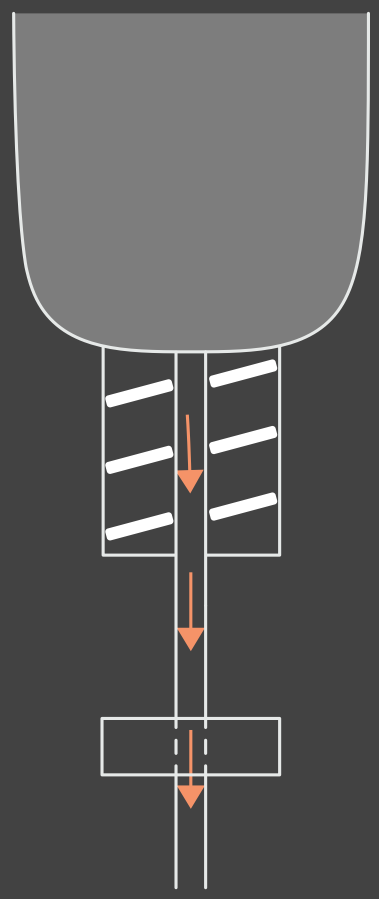
GANTRY CRANE
ROBOTIC PRINTER

3D PRINTING PROCESS

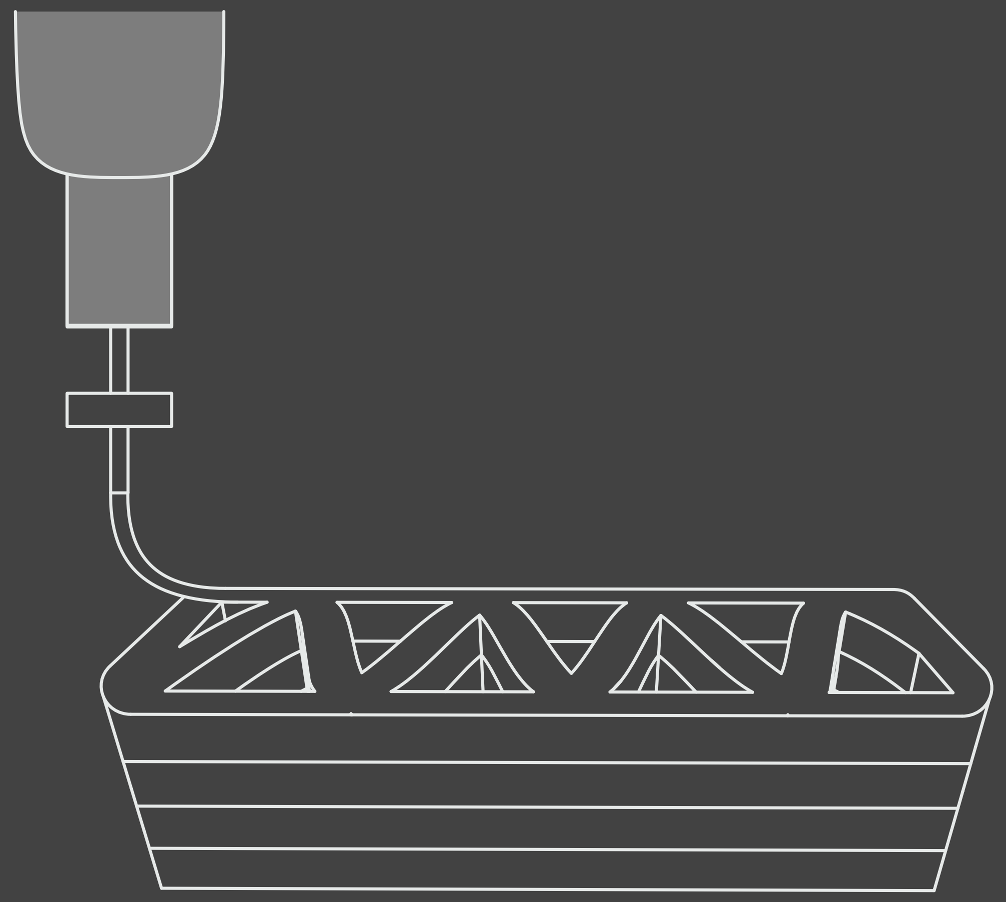


01 CONCRETE SUPPLY TO PRINTHEAD

CONCRETE 3D PRINTING PROCESS



02 DEPOSIT CONCRETE

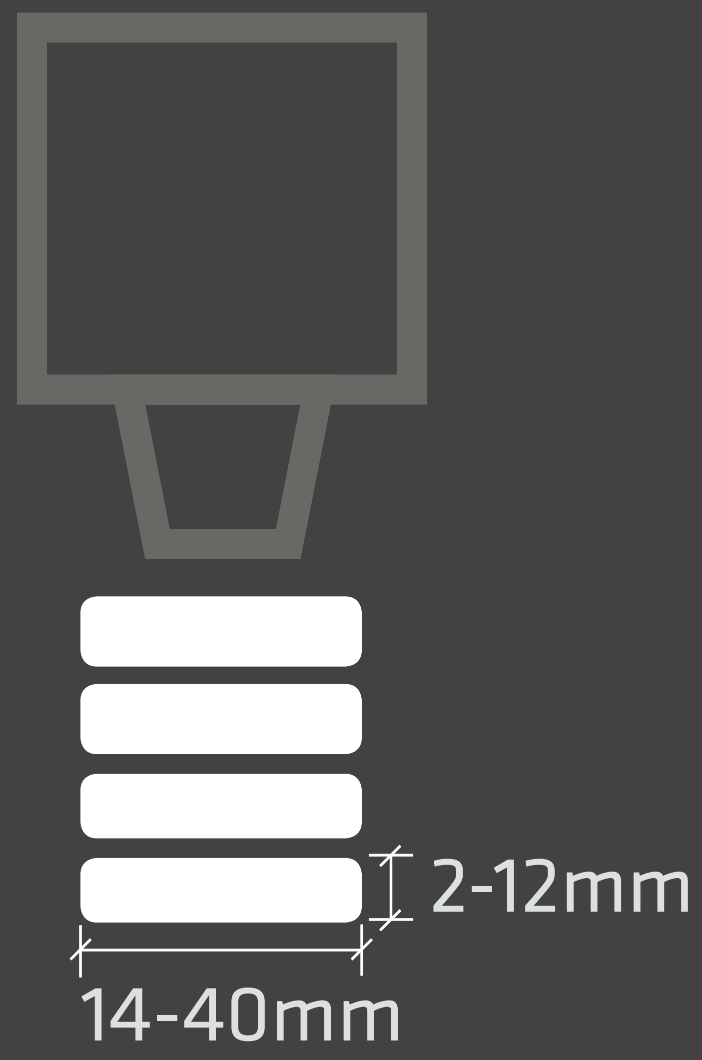


03 PRINT OBJECT BY LAYERS

CONCRETE 3D PRINTING PROCESS

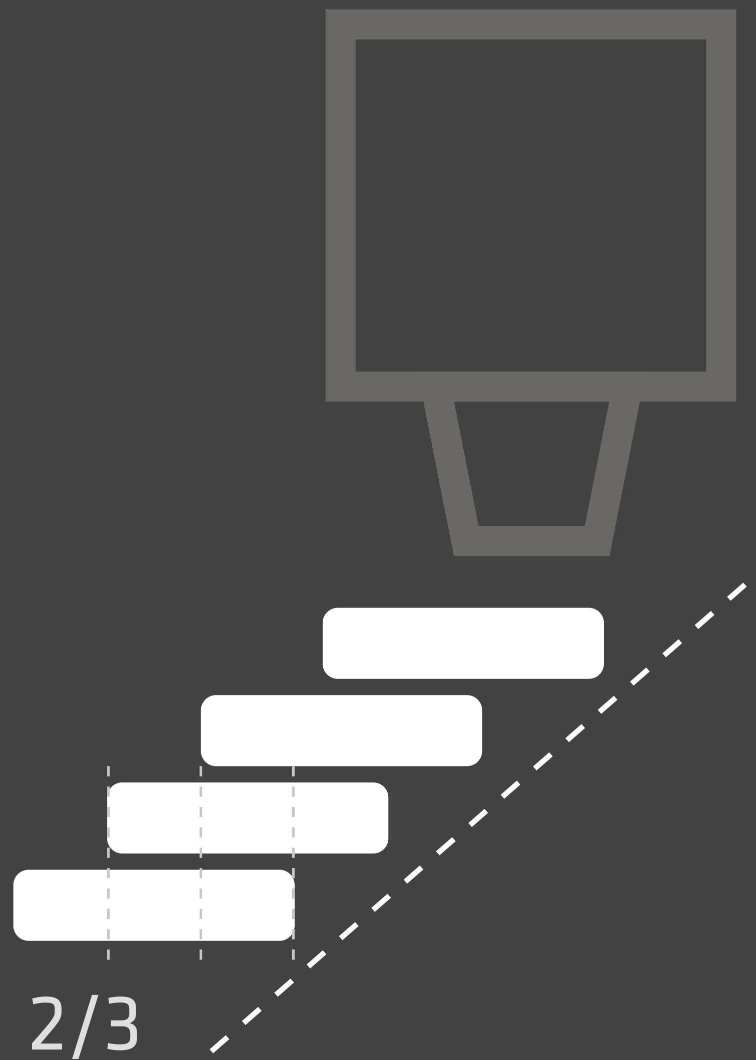
03

DESIGN GUIDELINES



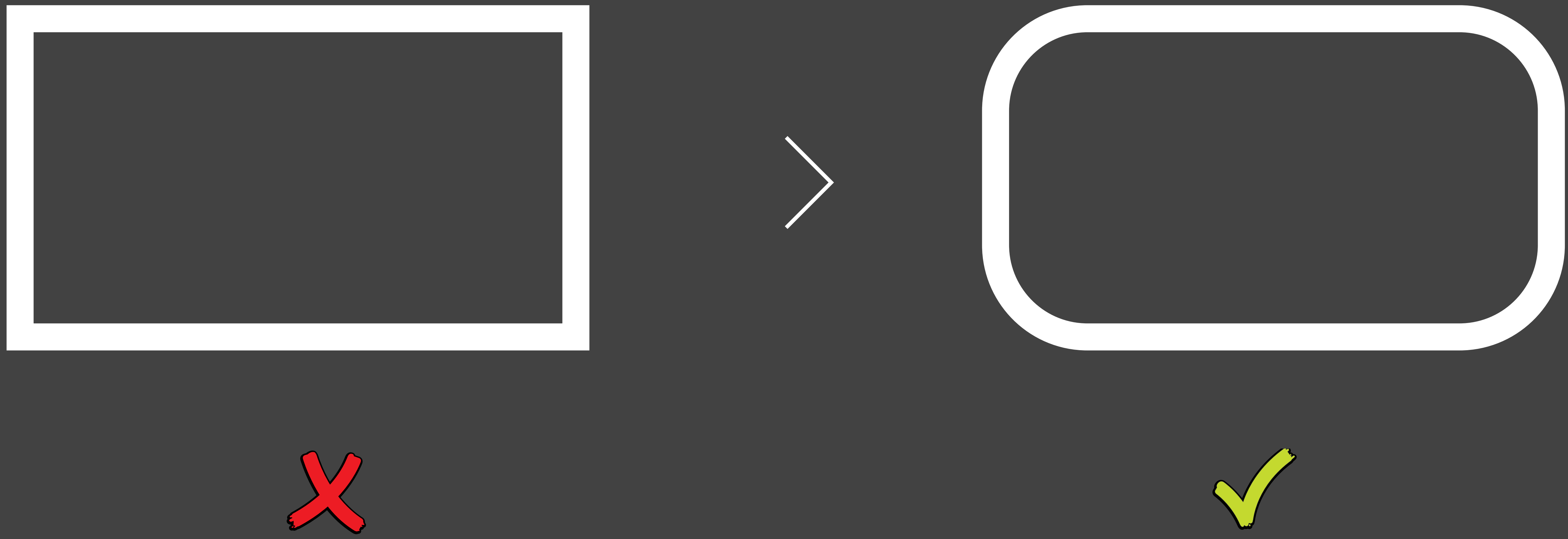
Typically, the maximum width for a layer is between 14mm and 40mm and the maximum layer height varies between 2mm and 12mm. It also varies based on different types of nozzles.

LAYER DIMENSIONS



The maximum cantilever is 2/3 of each layer based on the most advanced technology by Sika AG.

MAXIMUM ANGLE

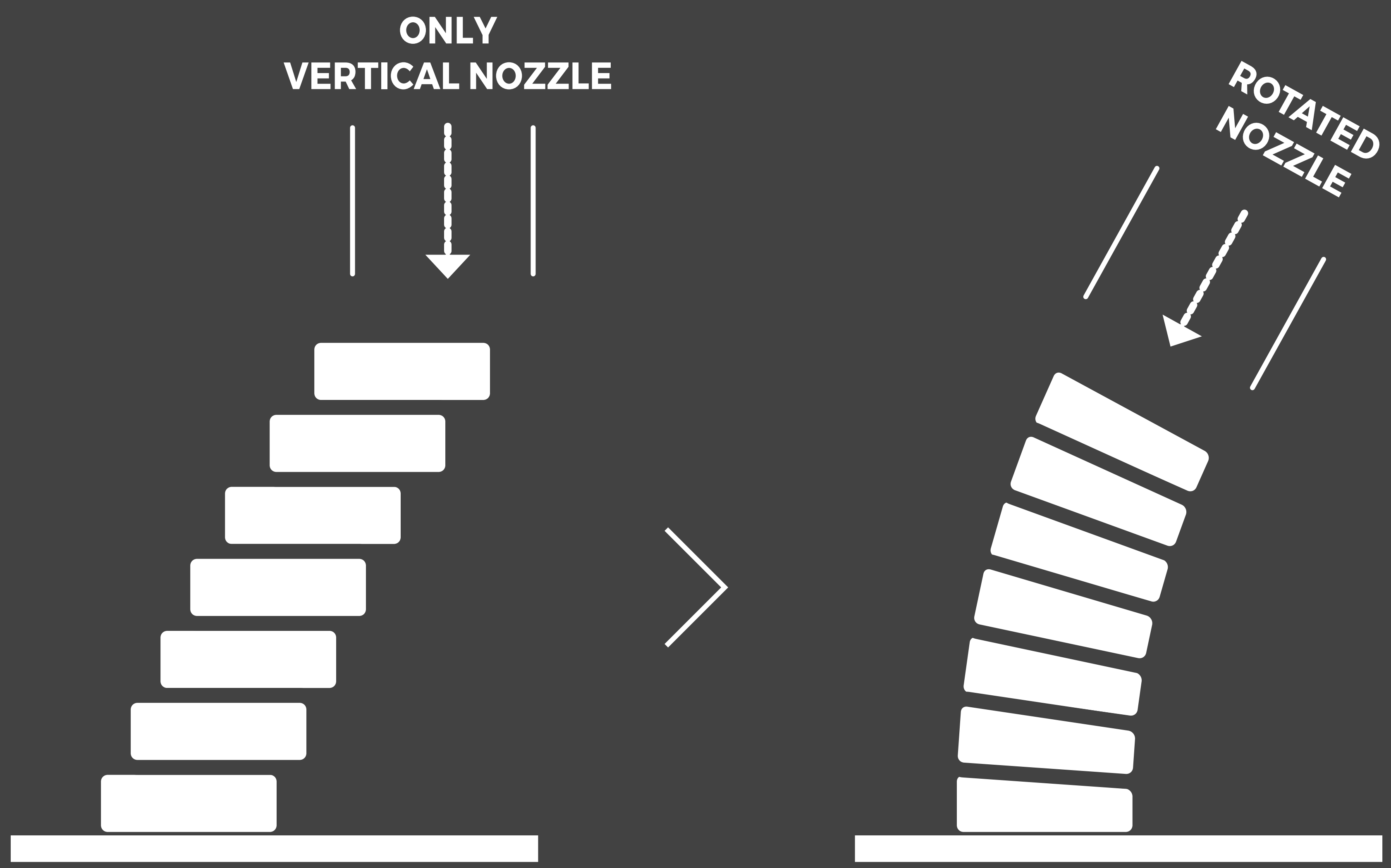


In plan, it is easier to make curves and fillets rather than sharp corners due to the movement of the machine.

CORNERS

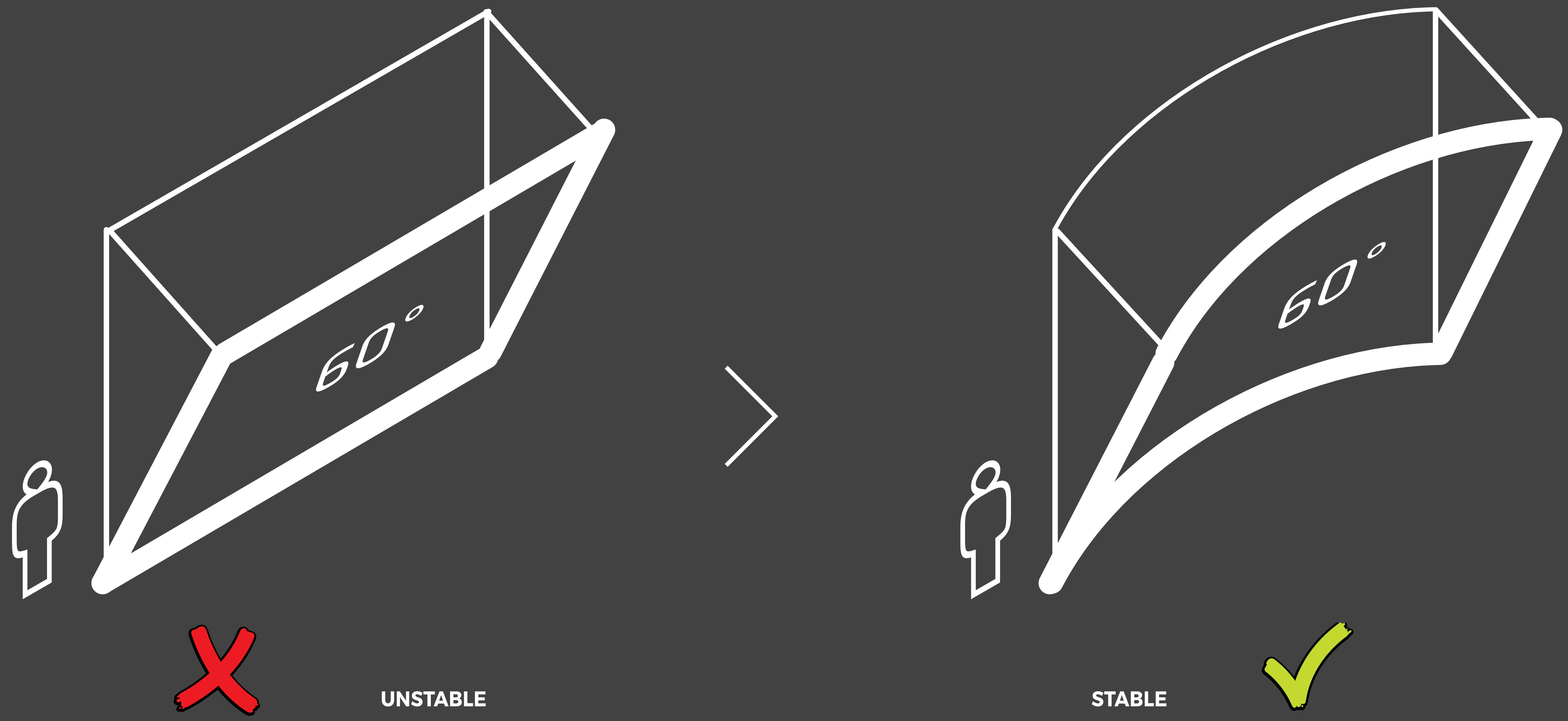
To be structurally stable and economically efficient, it is better to print a double wall instead of one thick wall. It saves material and the cavity space can be used for structure, insulation, piping, and perhaps even program.

LAYERS OF WALL



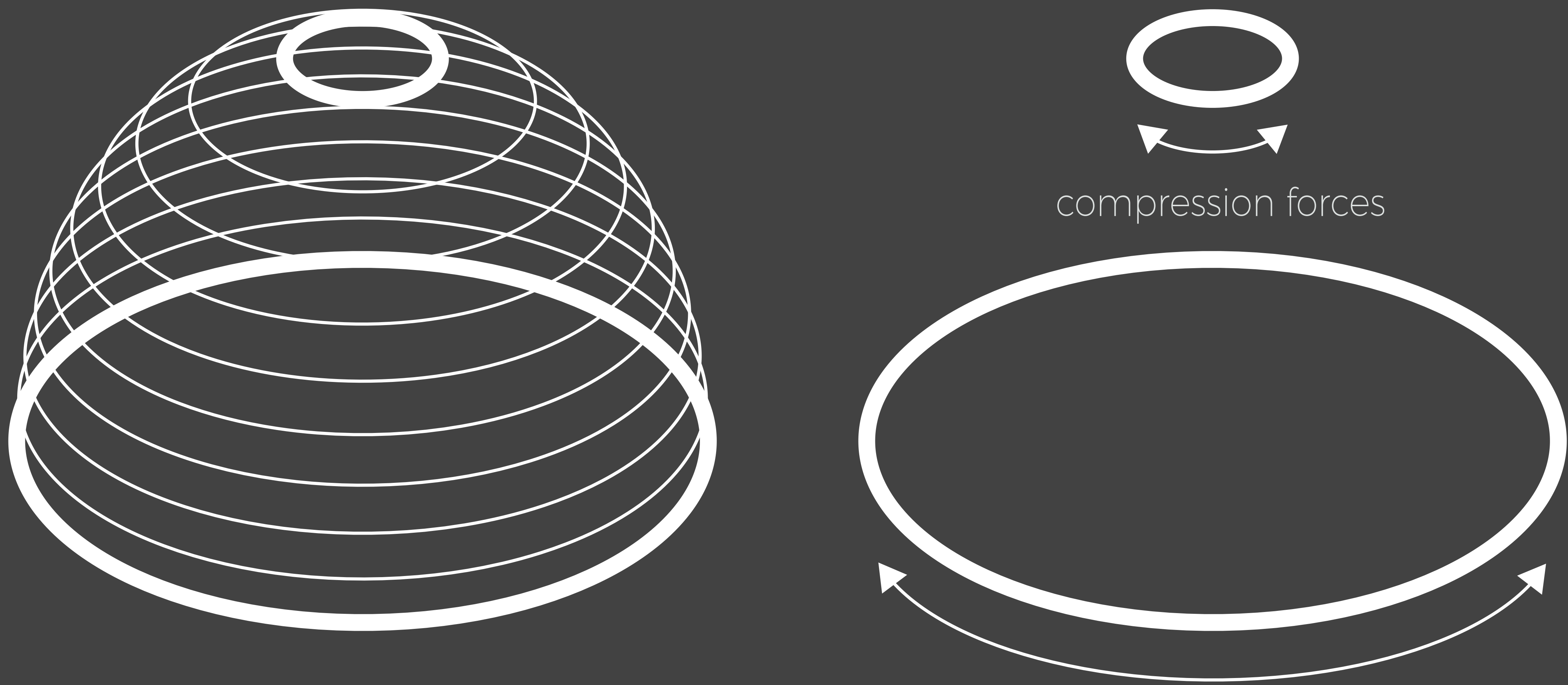
It is possible to consider the rotation of nozzle during the print. That could make the wall more structural, because each layer would adhere better to the layer below.

NOZZLE DIRECTION



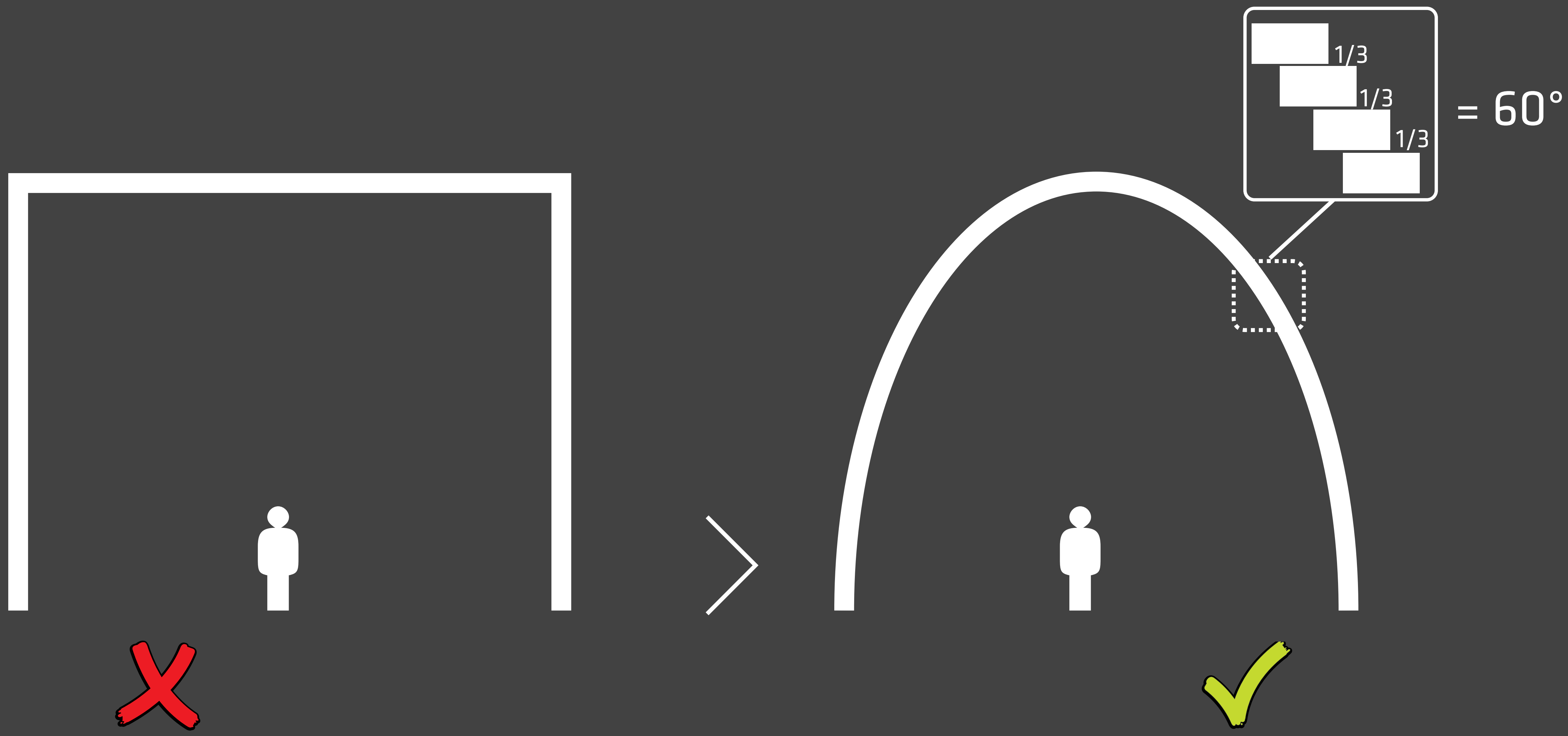
Based on a 60 degree angle cantilever, the max radius to make the wall stable. Ro illorundis nust, untio consequodiam custi rest qui aborum est voluptati idempor ma sim conectempora pa ipsa qui suntur, non cus nobitae perchil ma vollest otatas ella

STABLE CURVED WALL



The dome works only in compression. The steeper the angle, the smaller the radius.

RADIUS = -ANGLE (X)



Due to the nature of the extrusion technique, it is technically not possible to print horizontal members without scaffolding or other considerations. Maximum cantilever is 1/3 of each layer which is about 60 degree angle.

CANTILEVER

At the beginning of each layer's extrusion, it is difficult to control the ejection and precision.

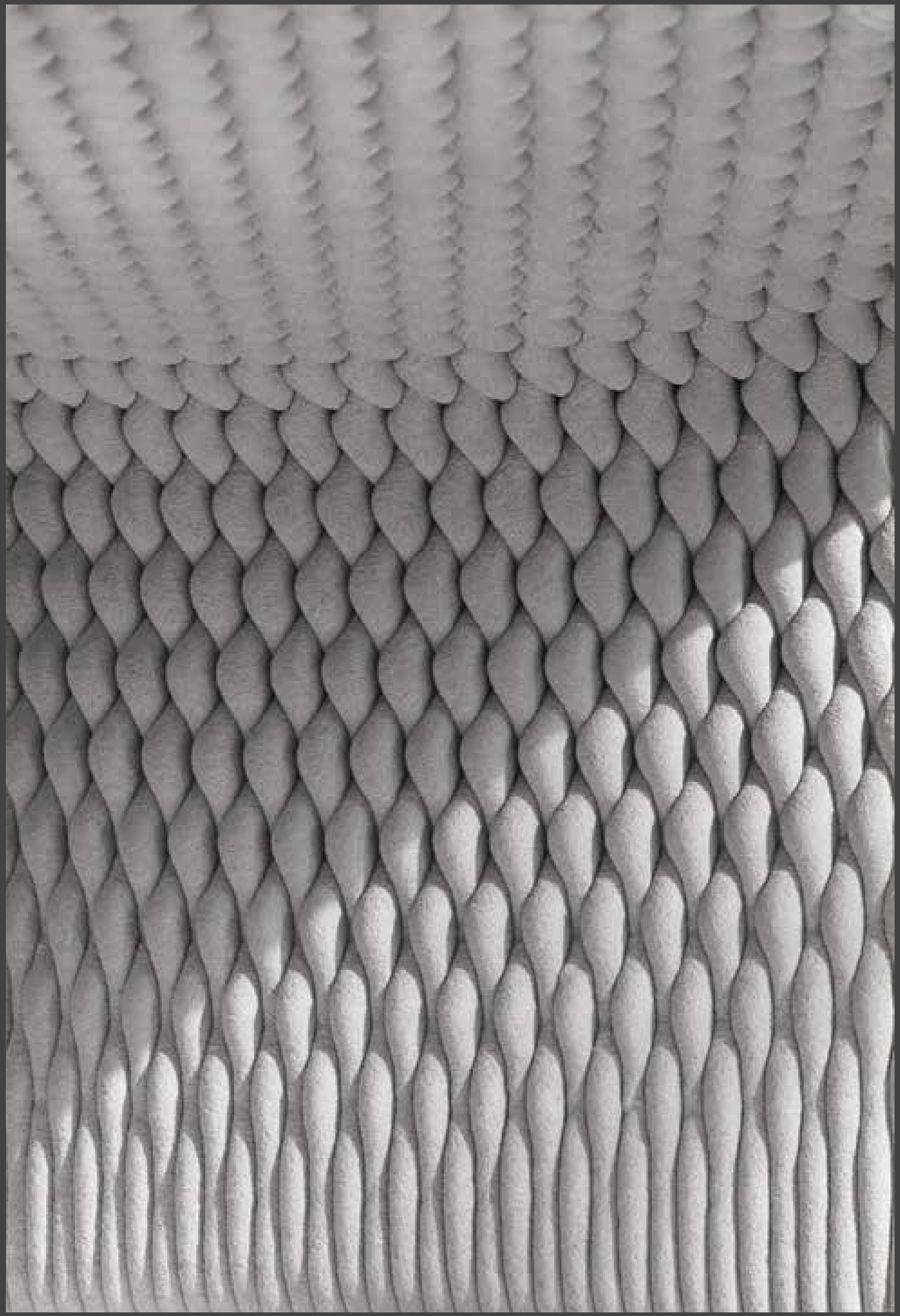
START OF PRINT

It is recommended to hide the starting point of the print or to integrate it within the structure.

START OF PRINT

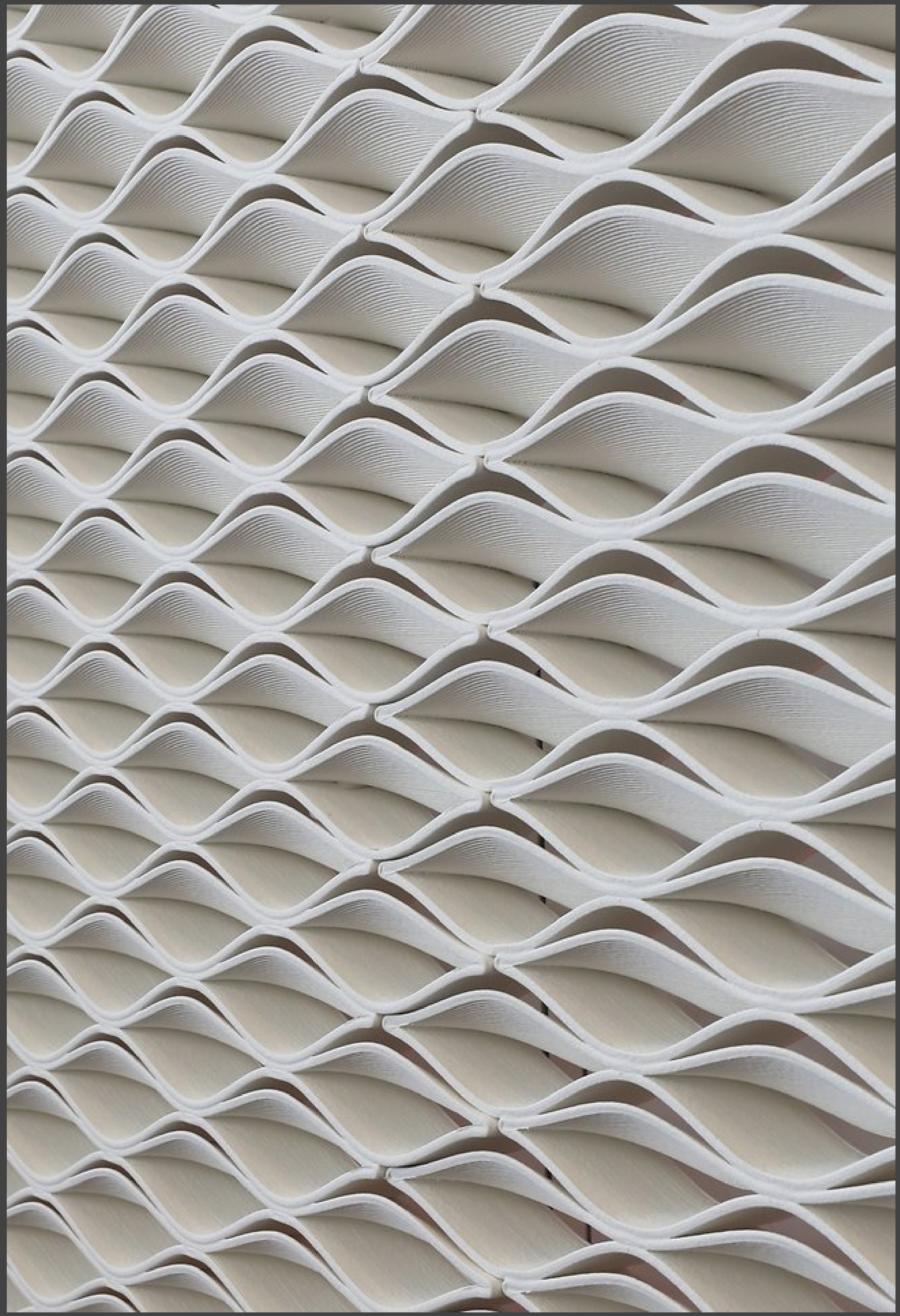
04

PRINTING FINISHES

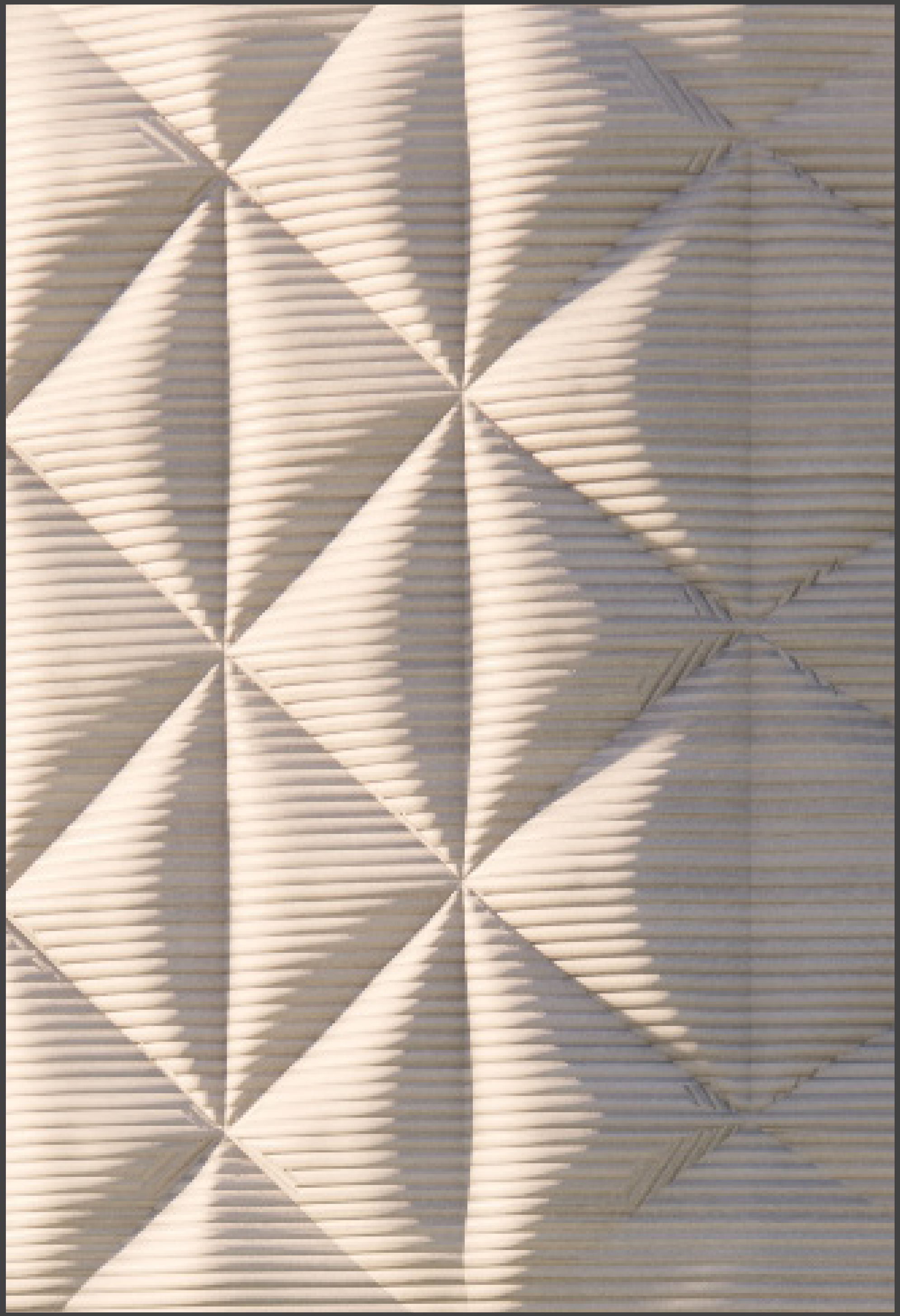


PATTERNS

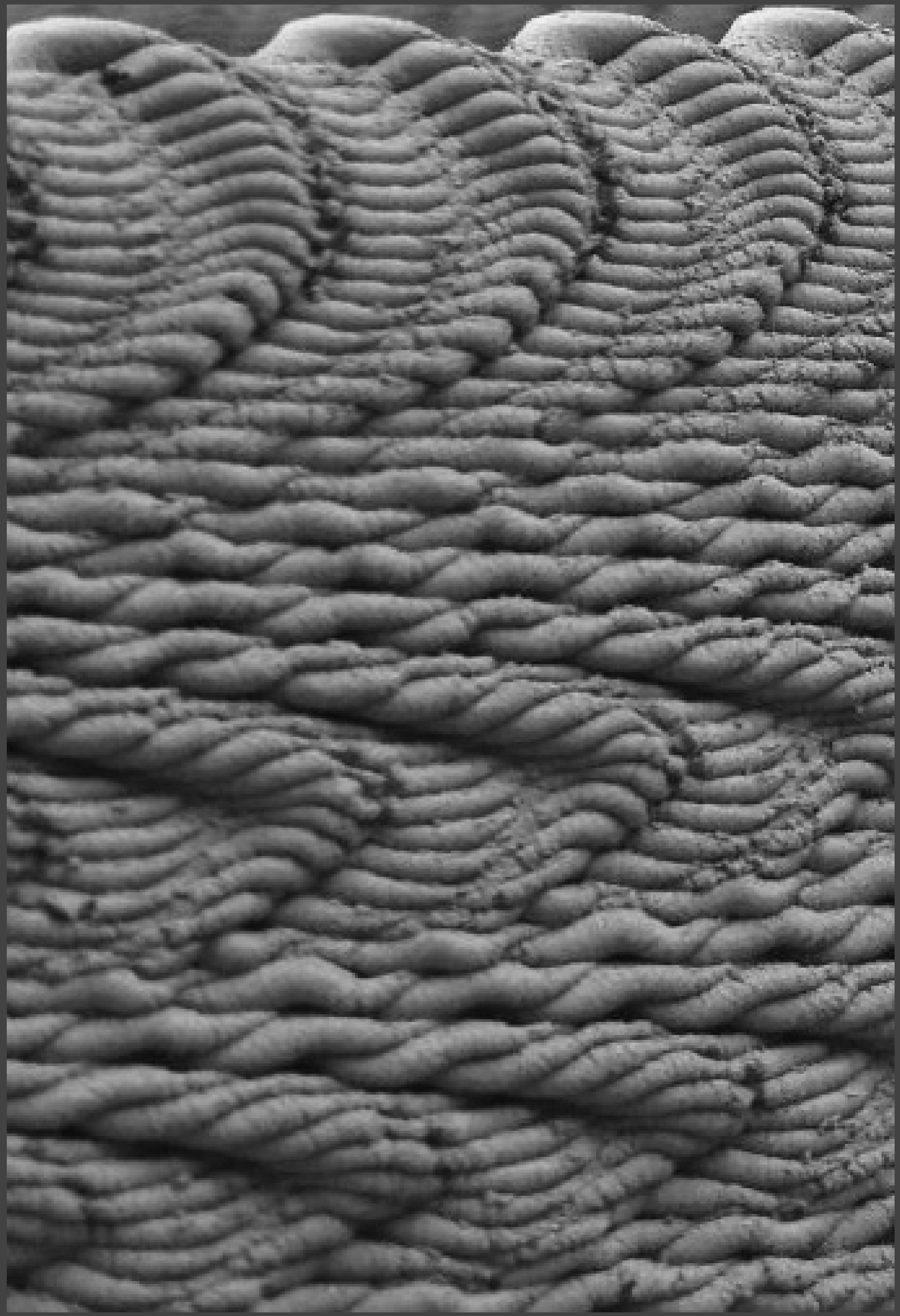
NON-PLANAR PRINTING & VARYING LAYER HEIGHT



LARGER PATTERNS



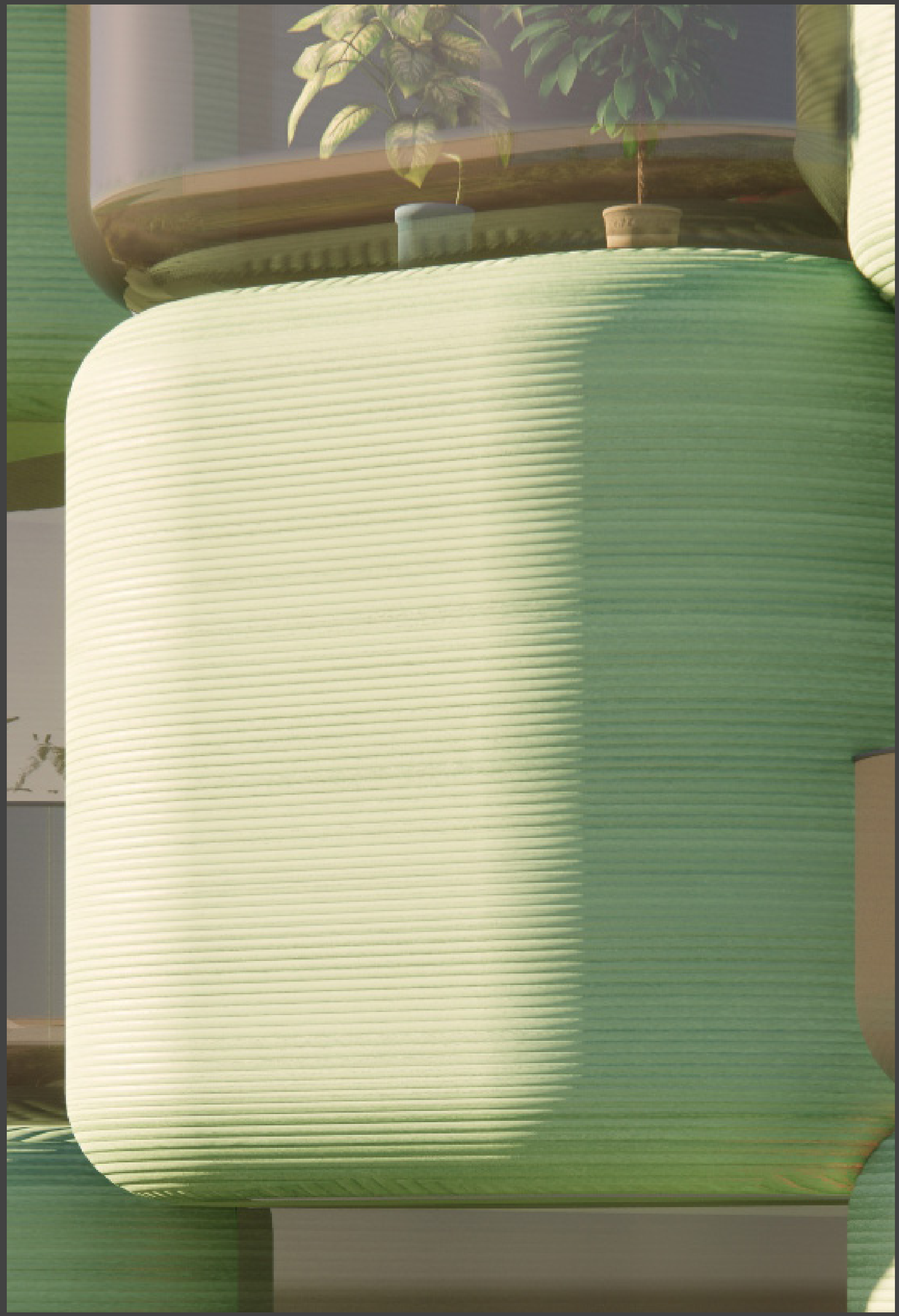
DIRECTION



NON-UNIFORM TEXTURE

WALL CURVATURE

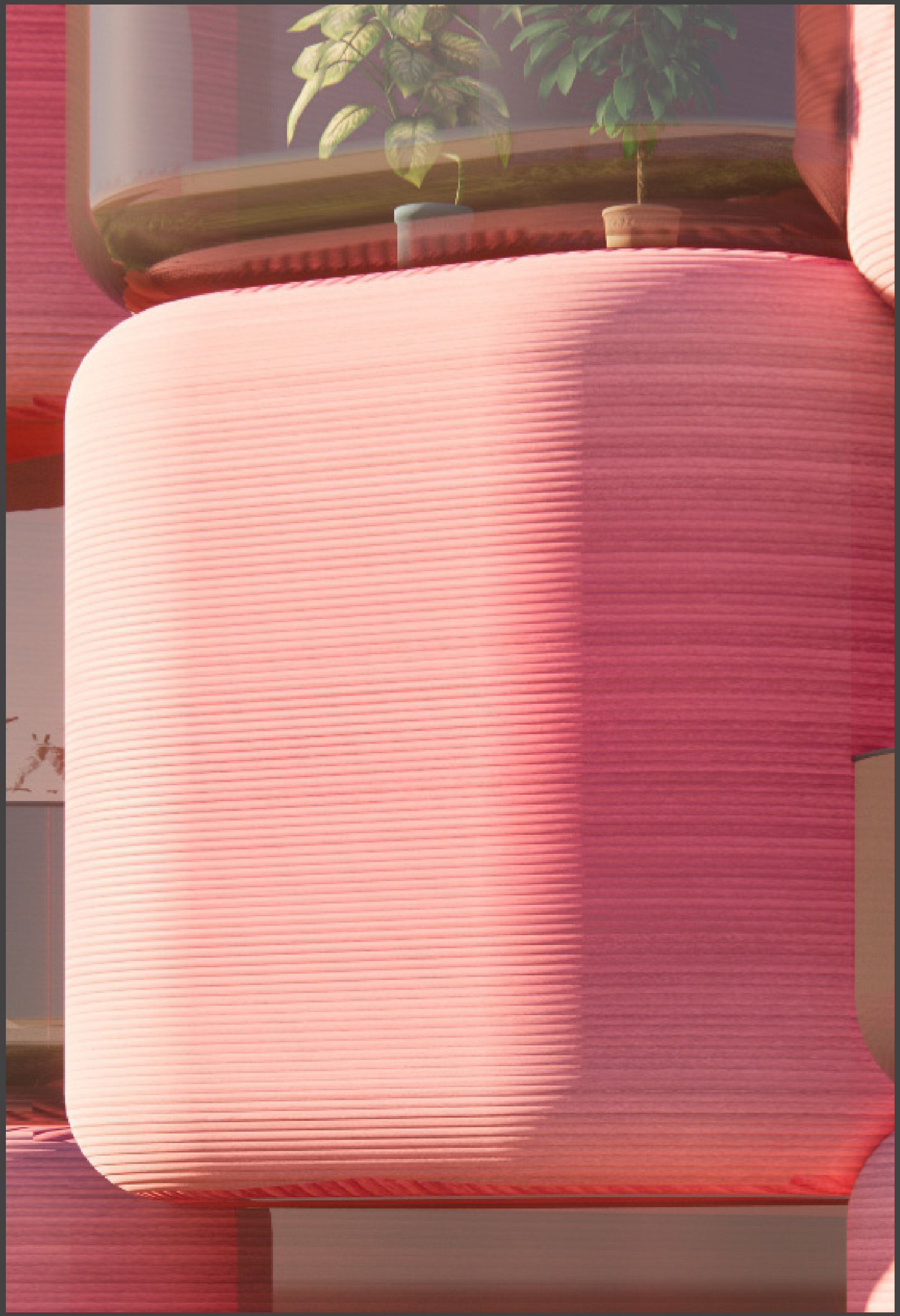
COLOR #1



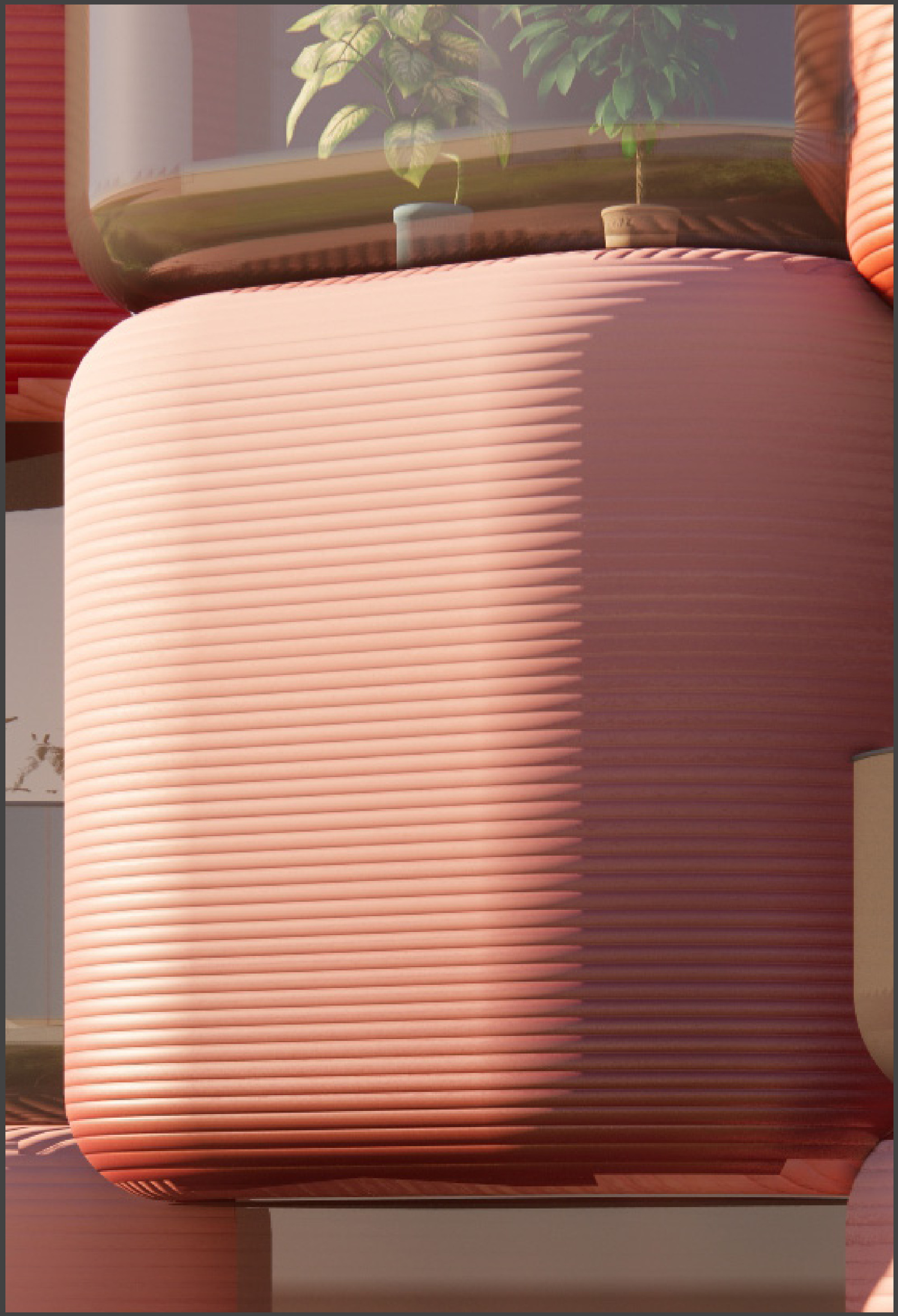
COLOR #2

COLOR #3

COLOR #4



COLOR #5



COLOR #6

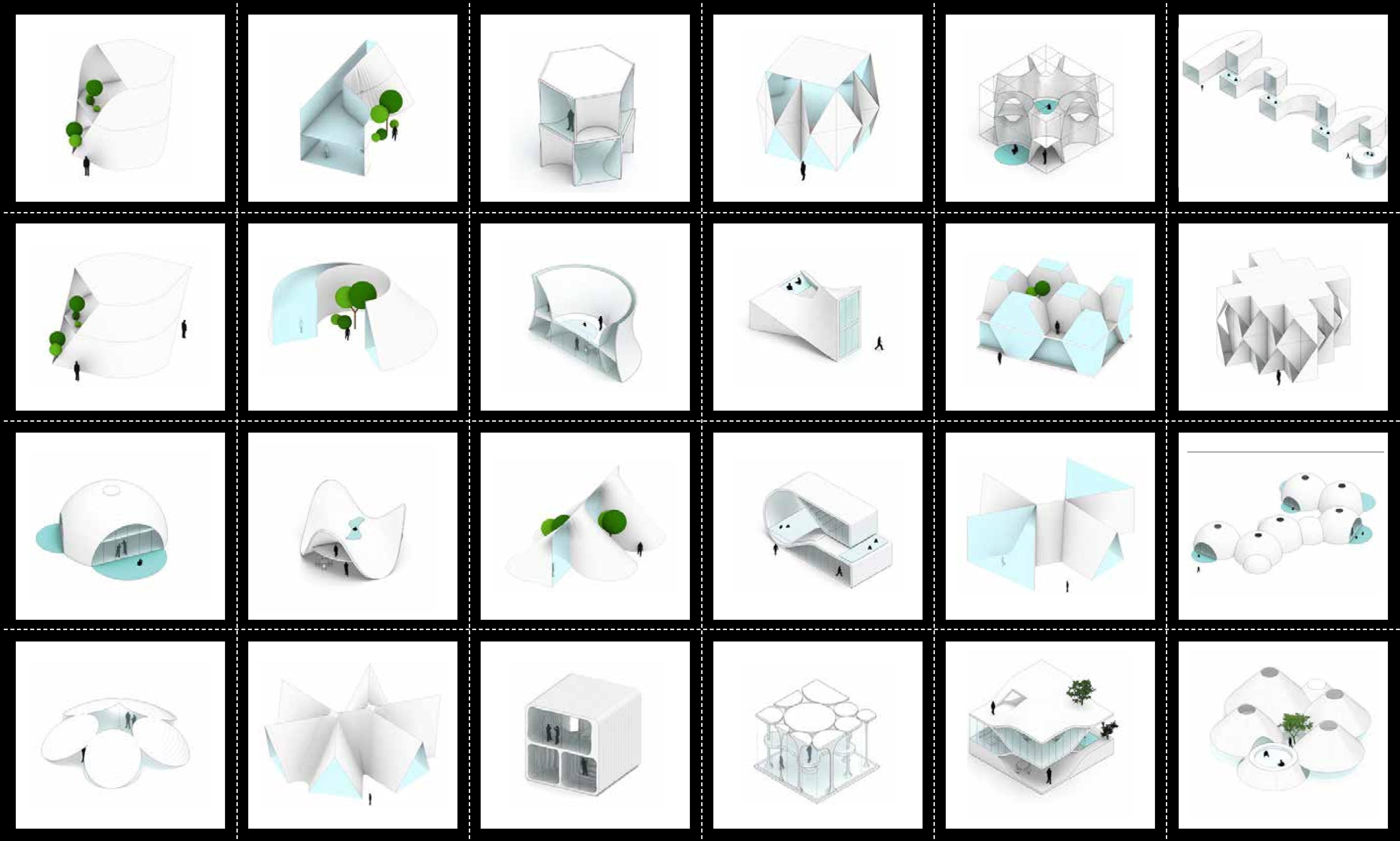
05

ON-SITE PRINT

BIG

MATRIX - OVERVIEW

SINGLE

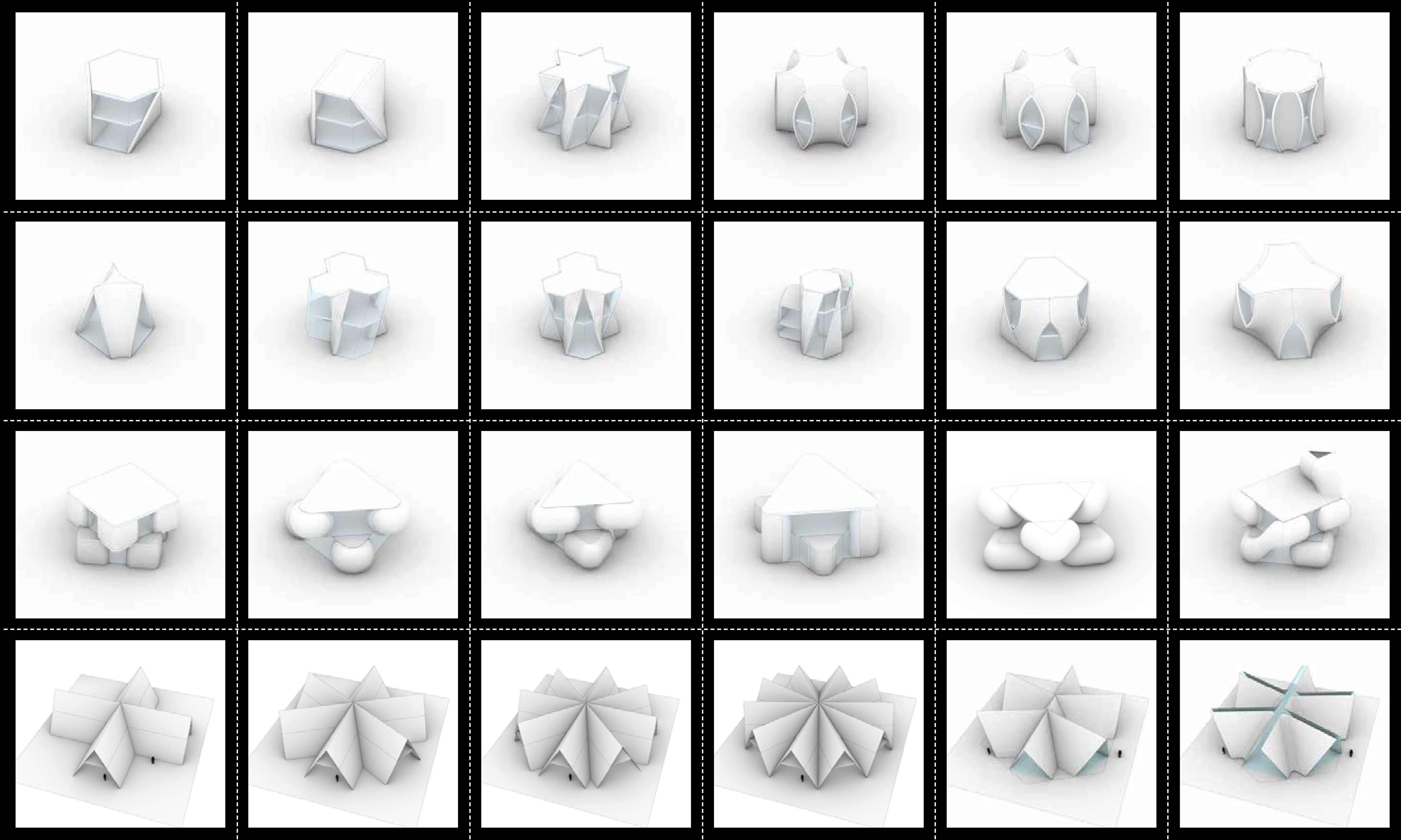


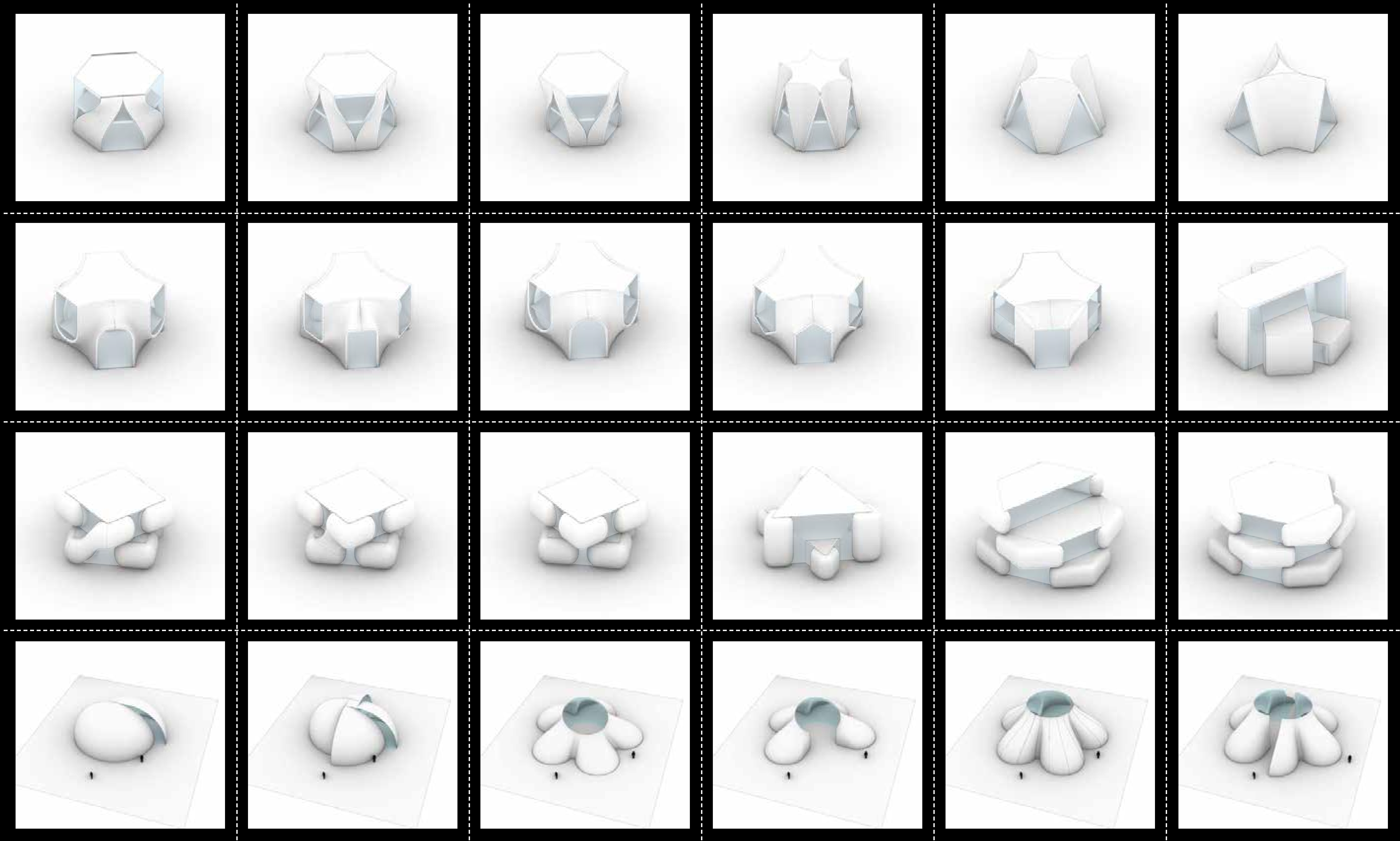
MULTIPLE

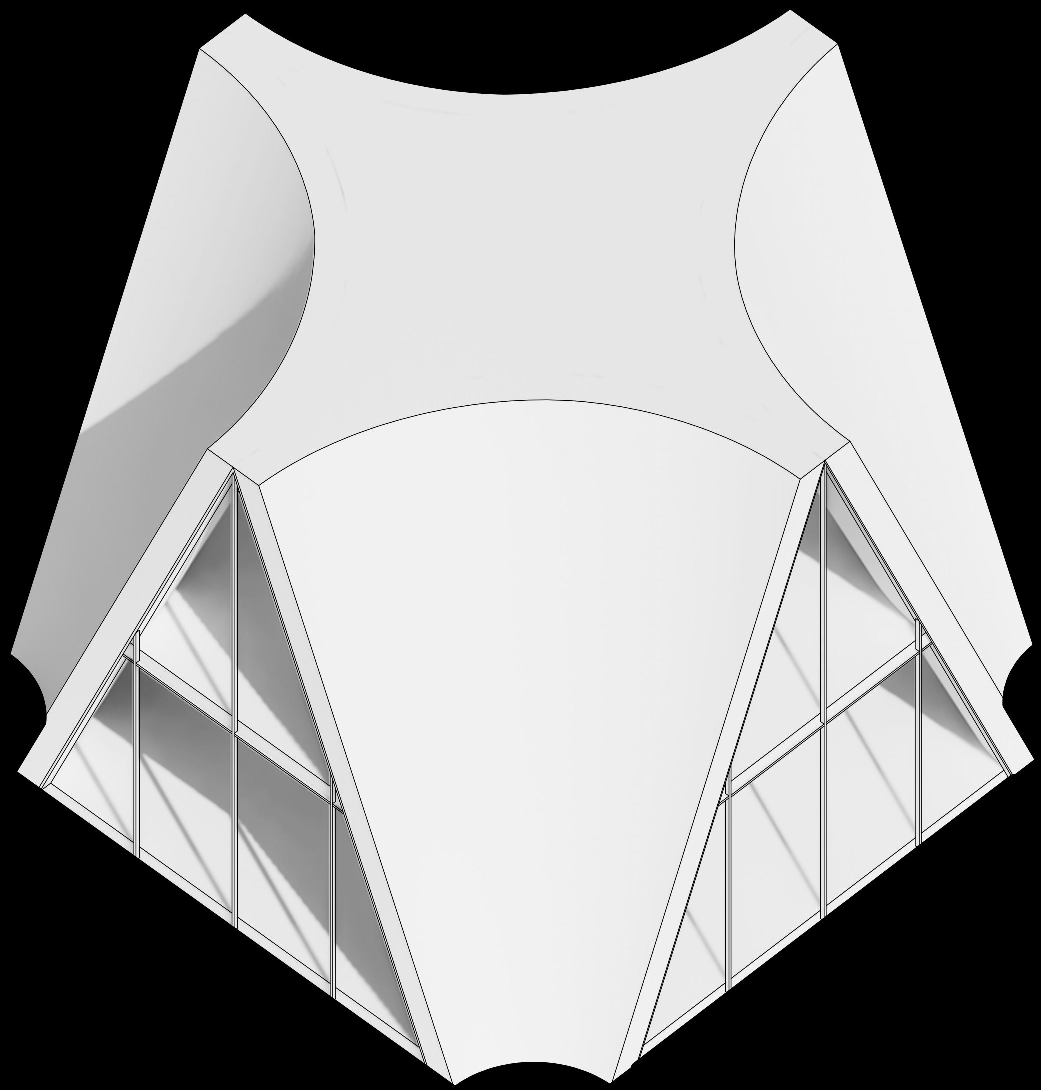
SINGLE

MULTIPLE

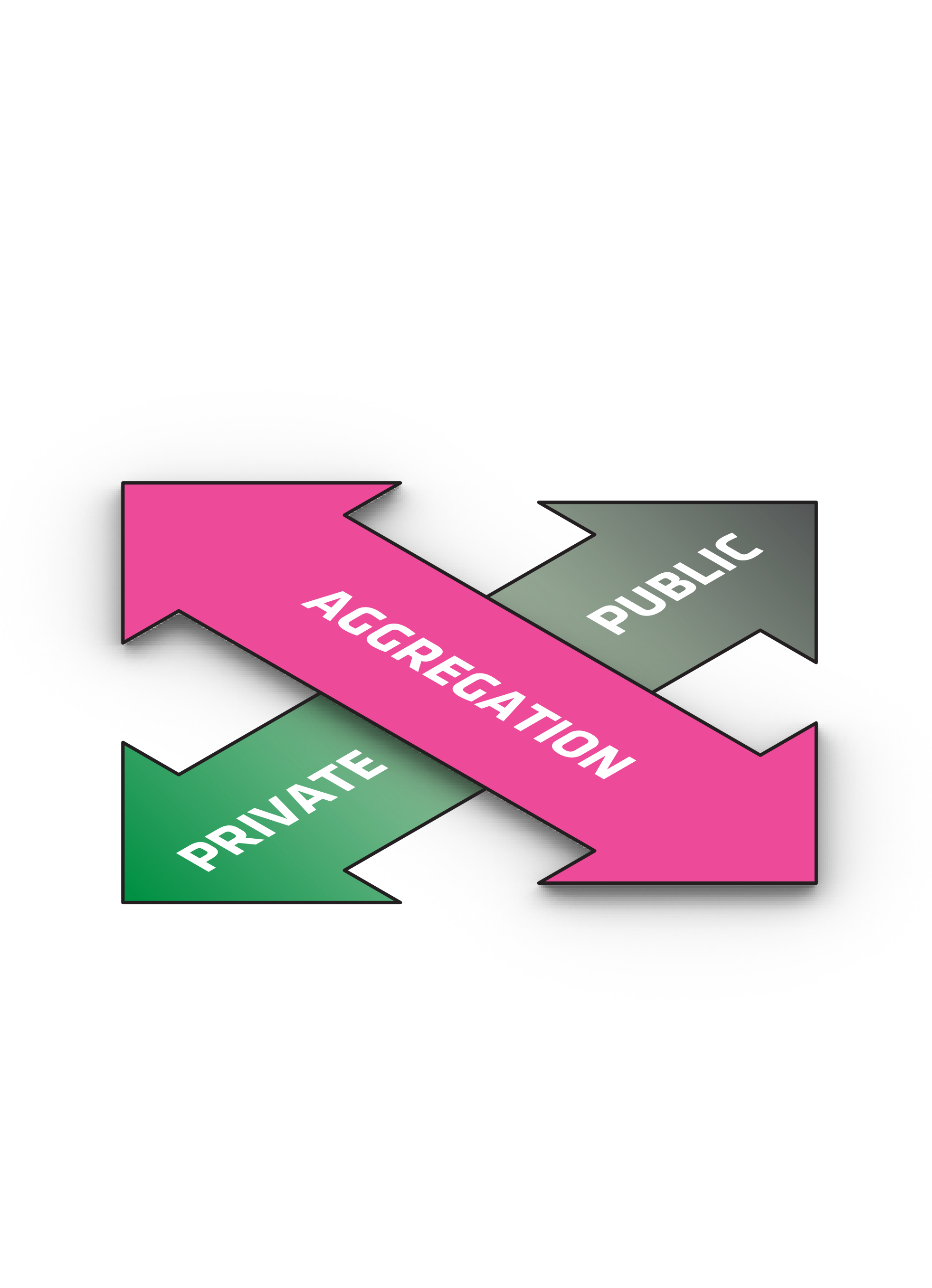
ON-SITE PRINT
MATRIX - OVERVIEW



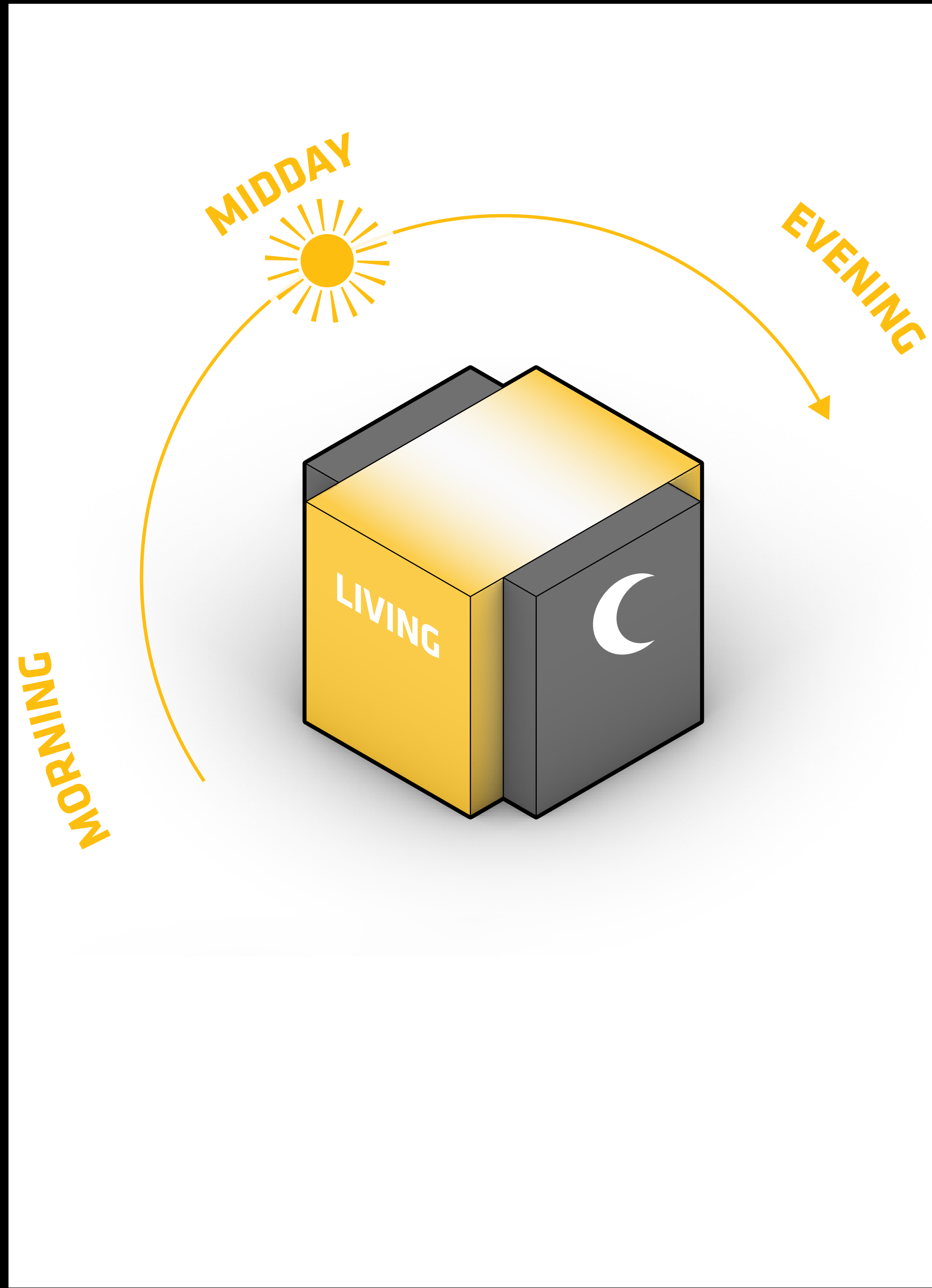




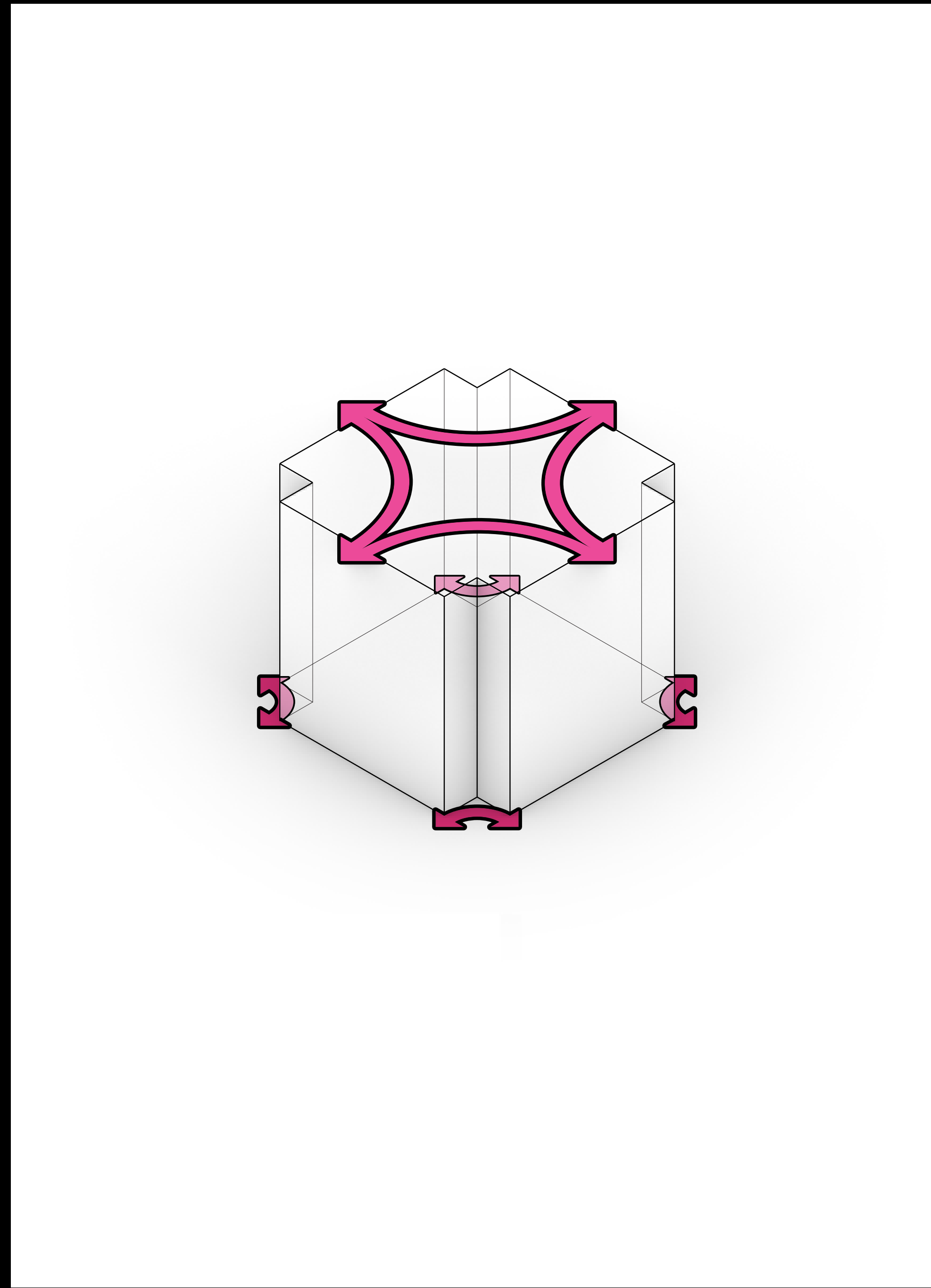
BIG - ROW HOUSE
OPTION A



DIRECTION

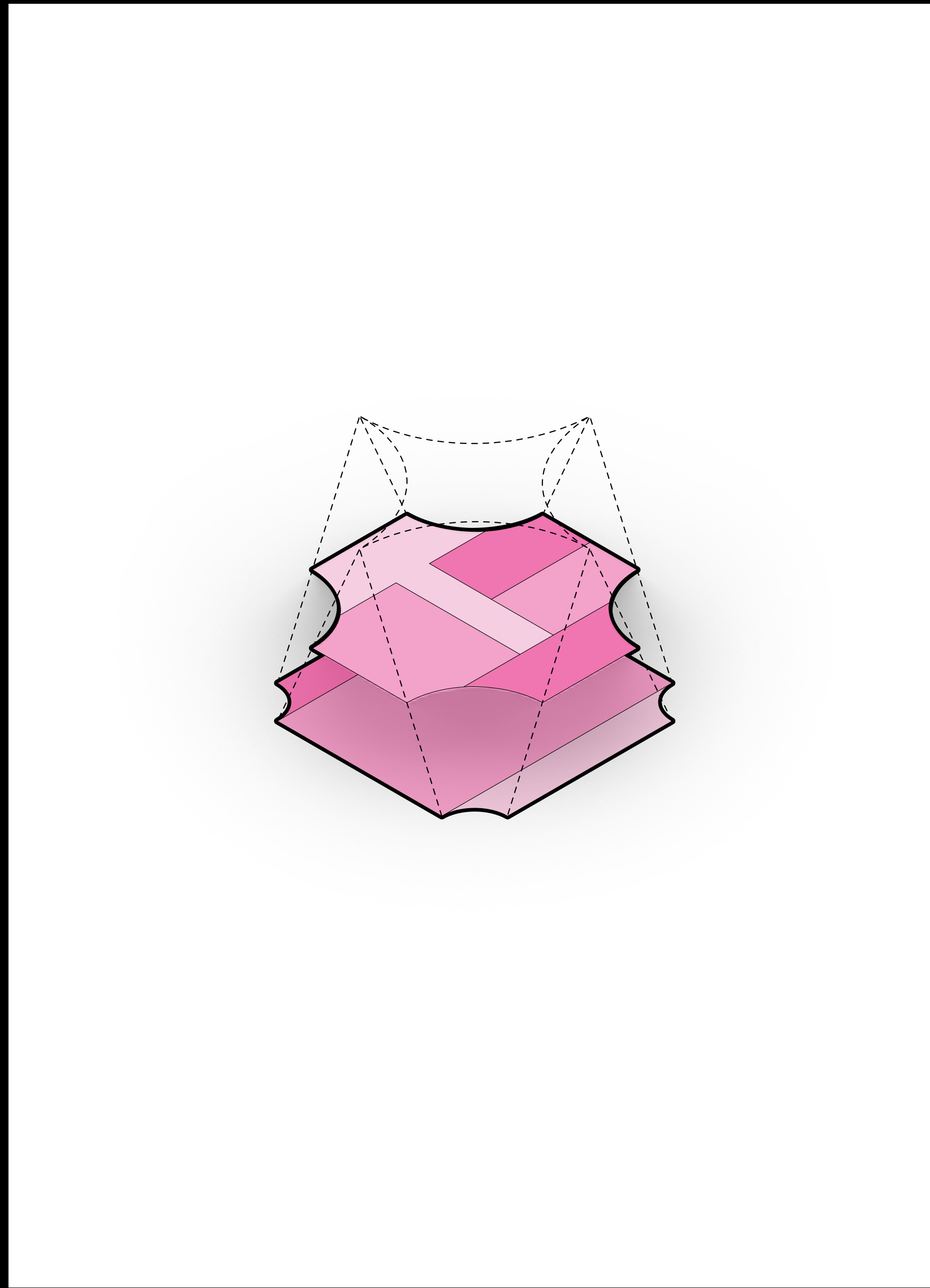


PROGRAM ZONING



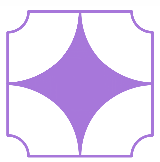
WALL CURVATURE

SHELL



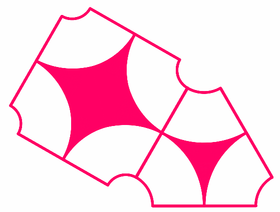
FLOOR PLAN

CABIN



UNIT A

FROUND FLOOR:	**68M²**
1ST FLOOR	**53M²**
TOTAL:	**121M²**



UNIT B

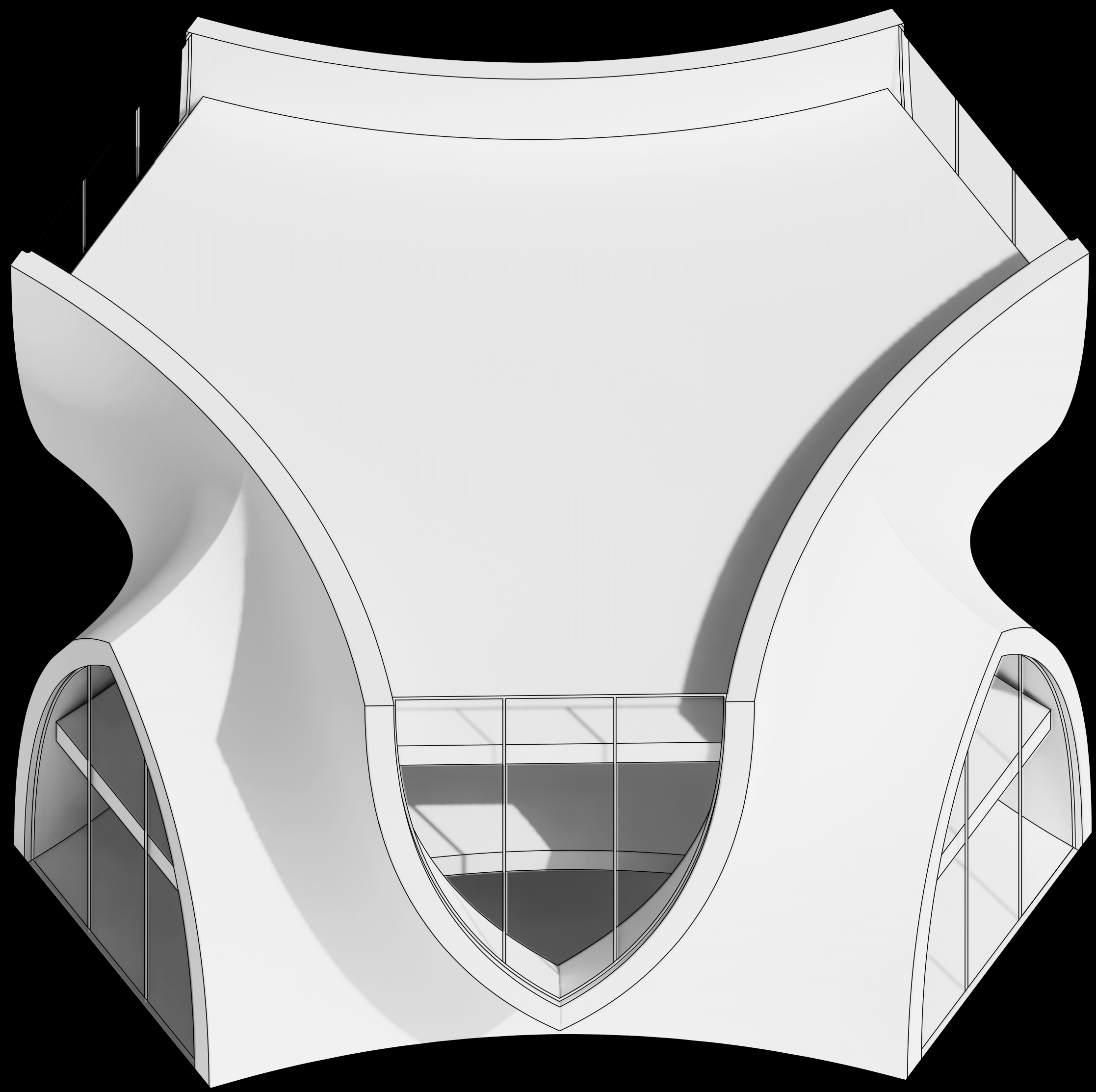
FROUND FLOOR:	**100M²**
1ST FLOOR	**80M²**
TOTAL:	**180M²**

UNIT C

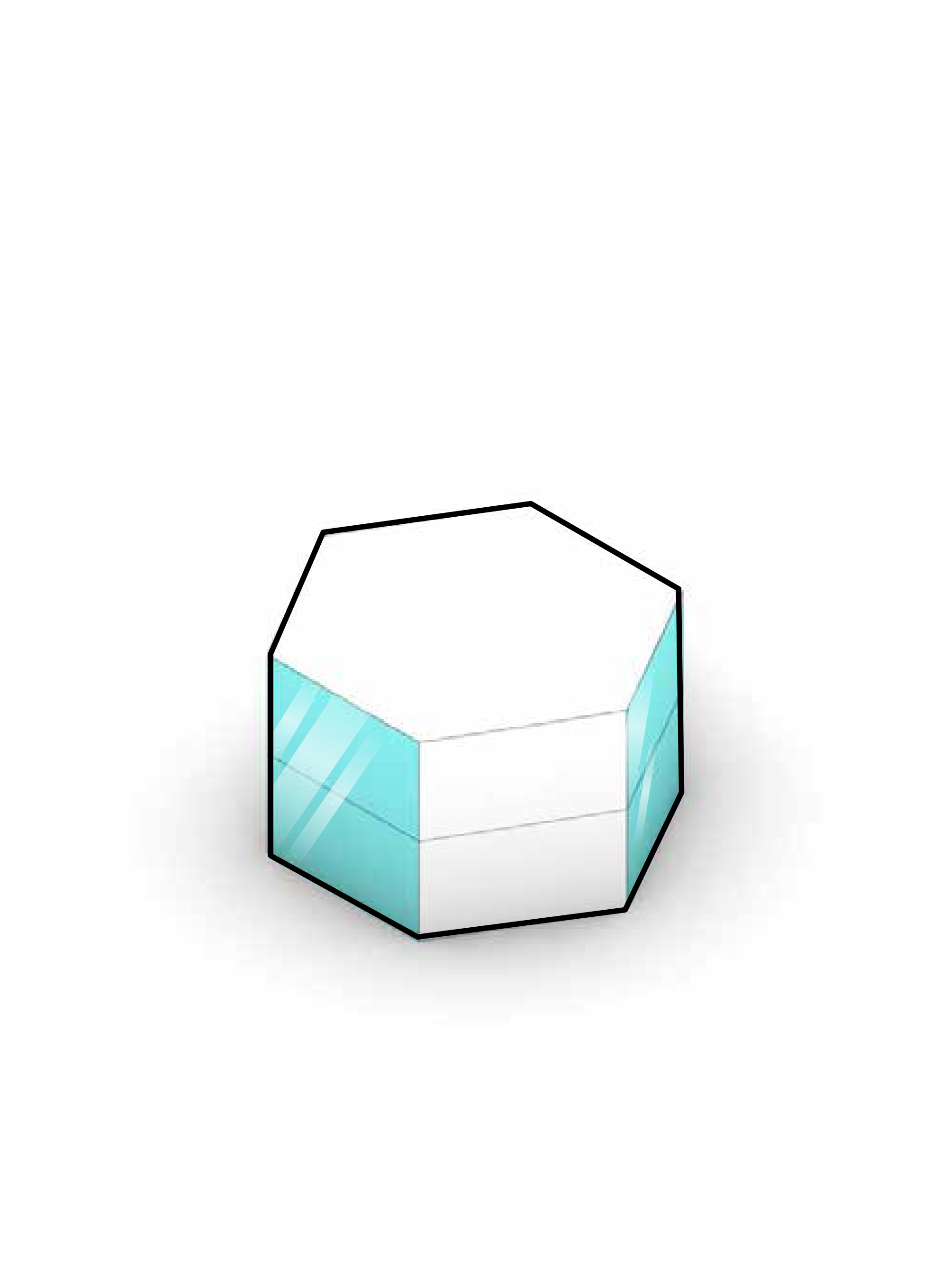
FROUND FLOOR:	**48M²**
1ST FLOOR	**73M²**
TOTAL:	**121M²**

UNIT TYPOLOGY

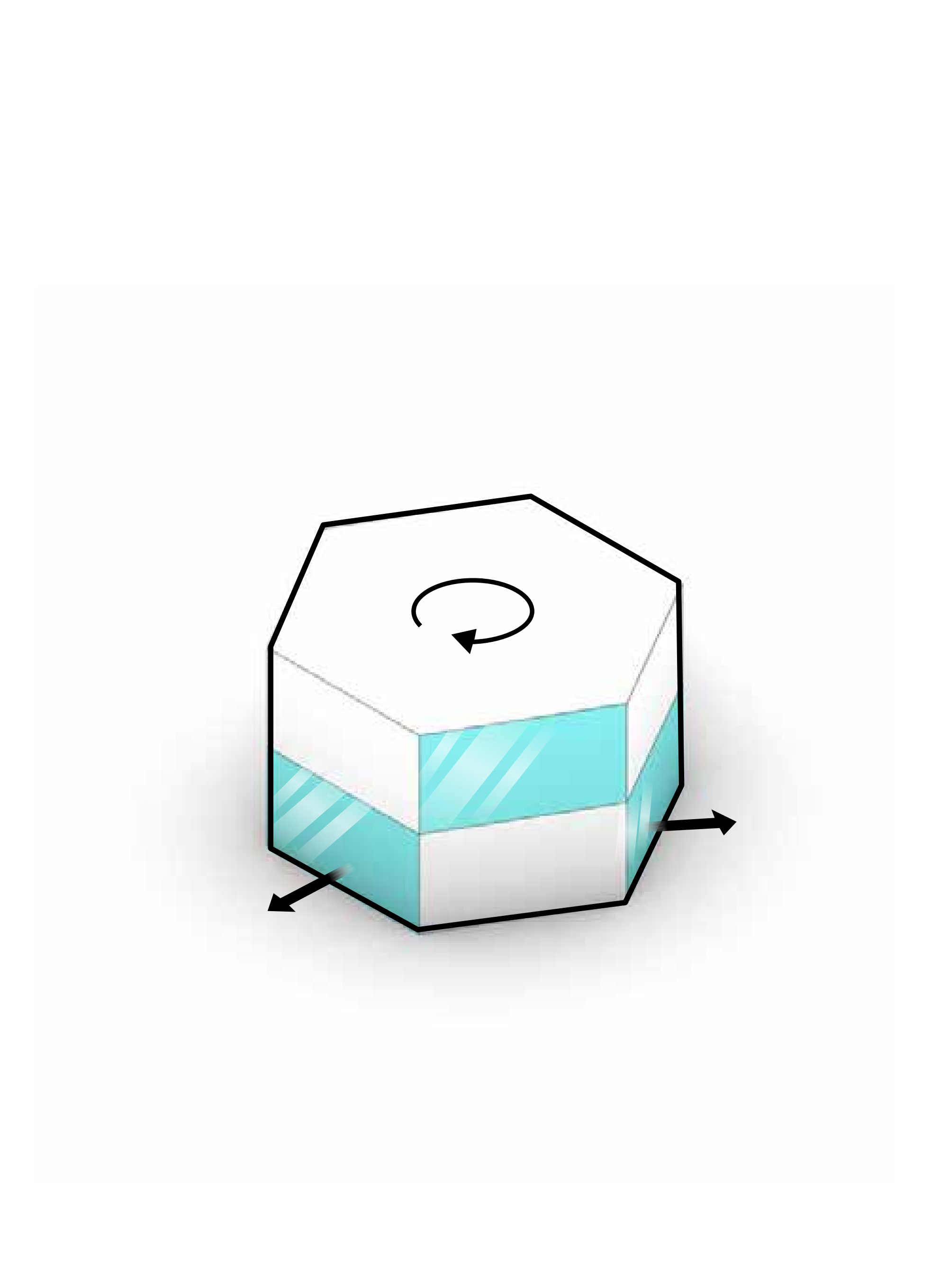
AGGREGATION



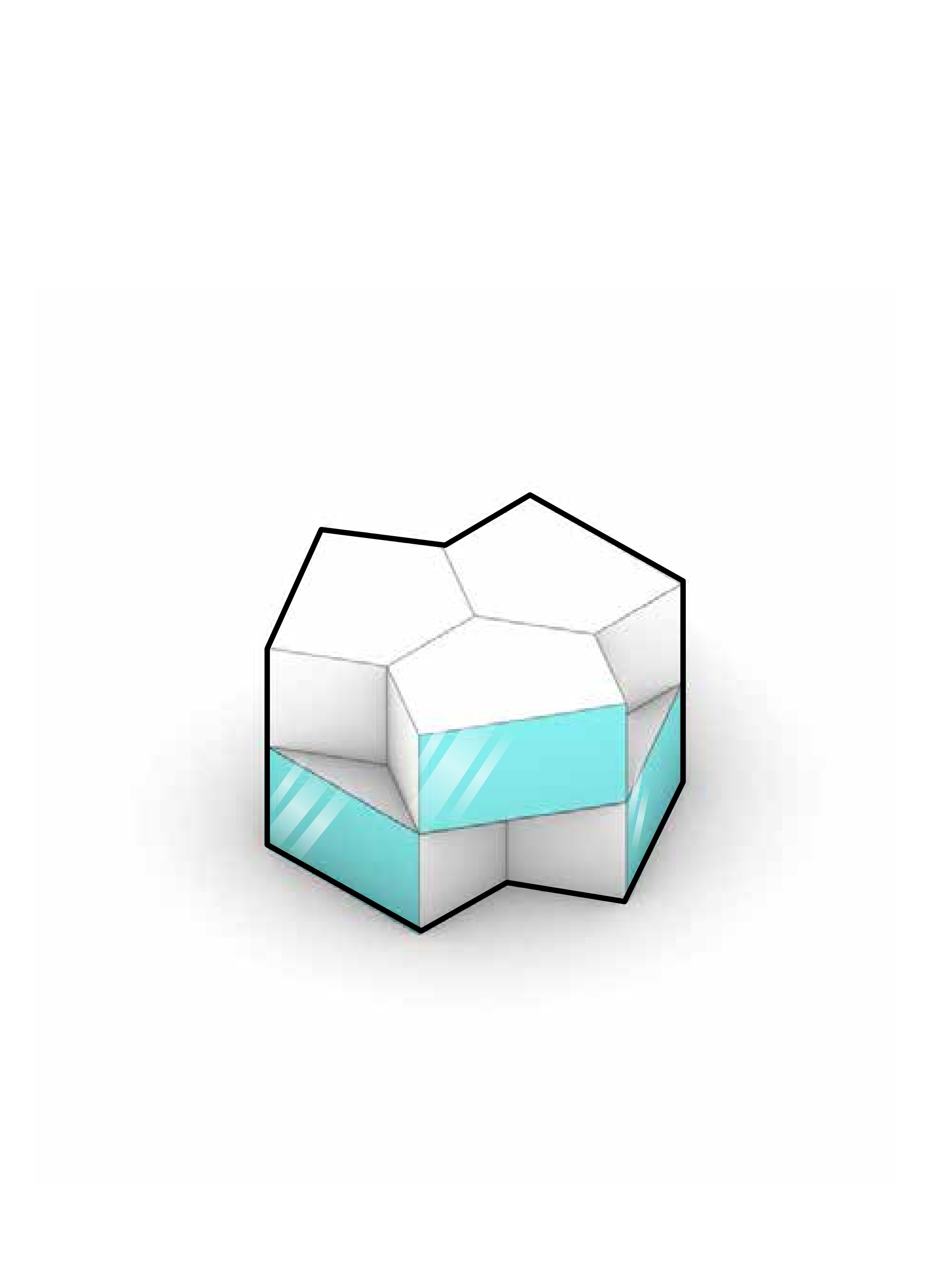
BIG - ROW HOUSE
OPTION B



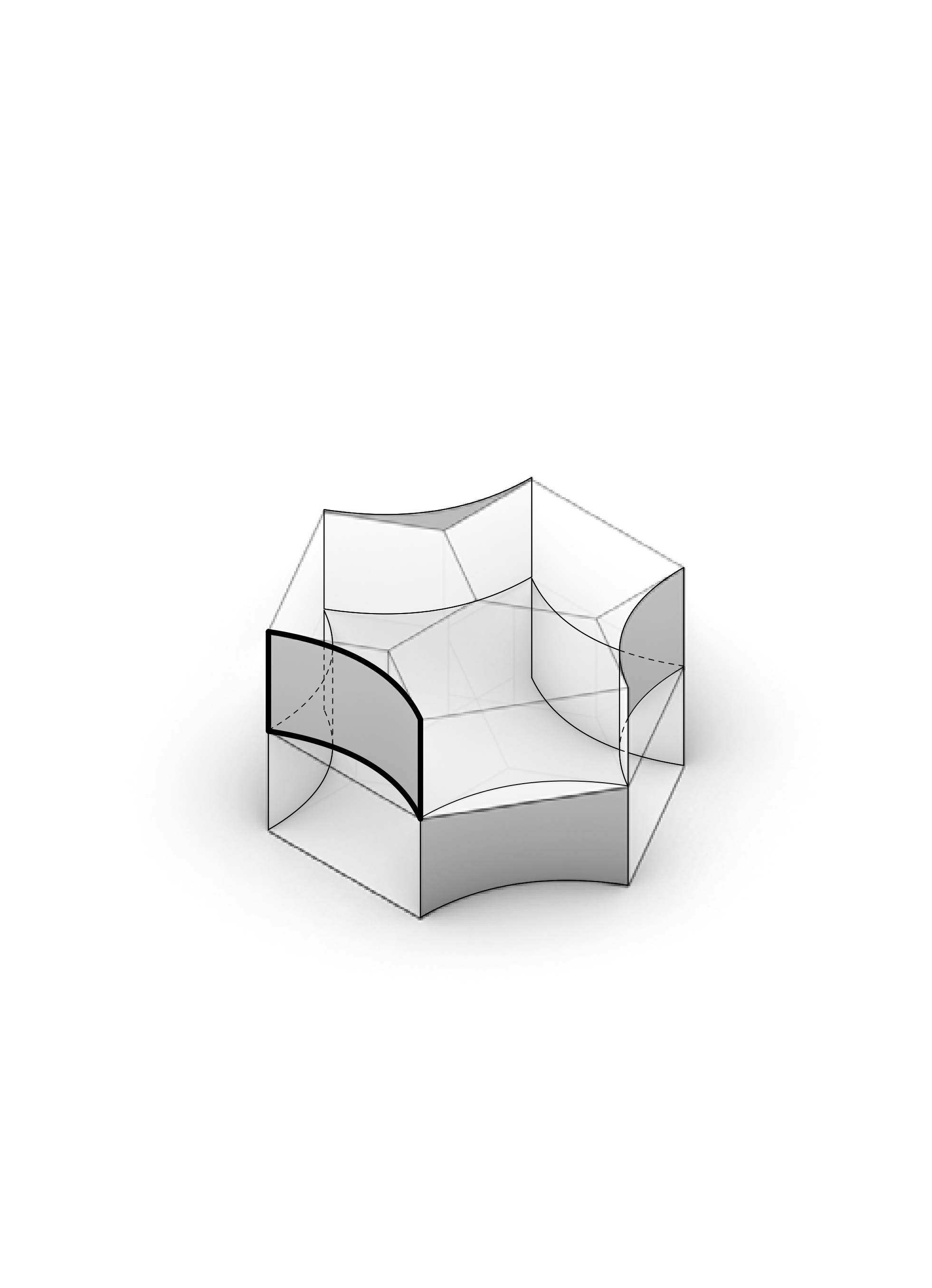
GLAZING



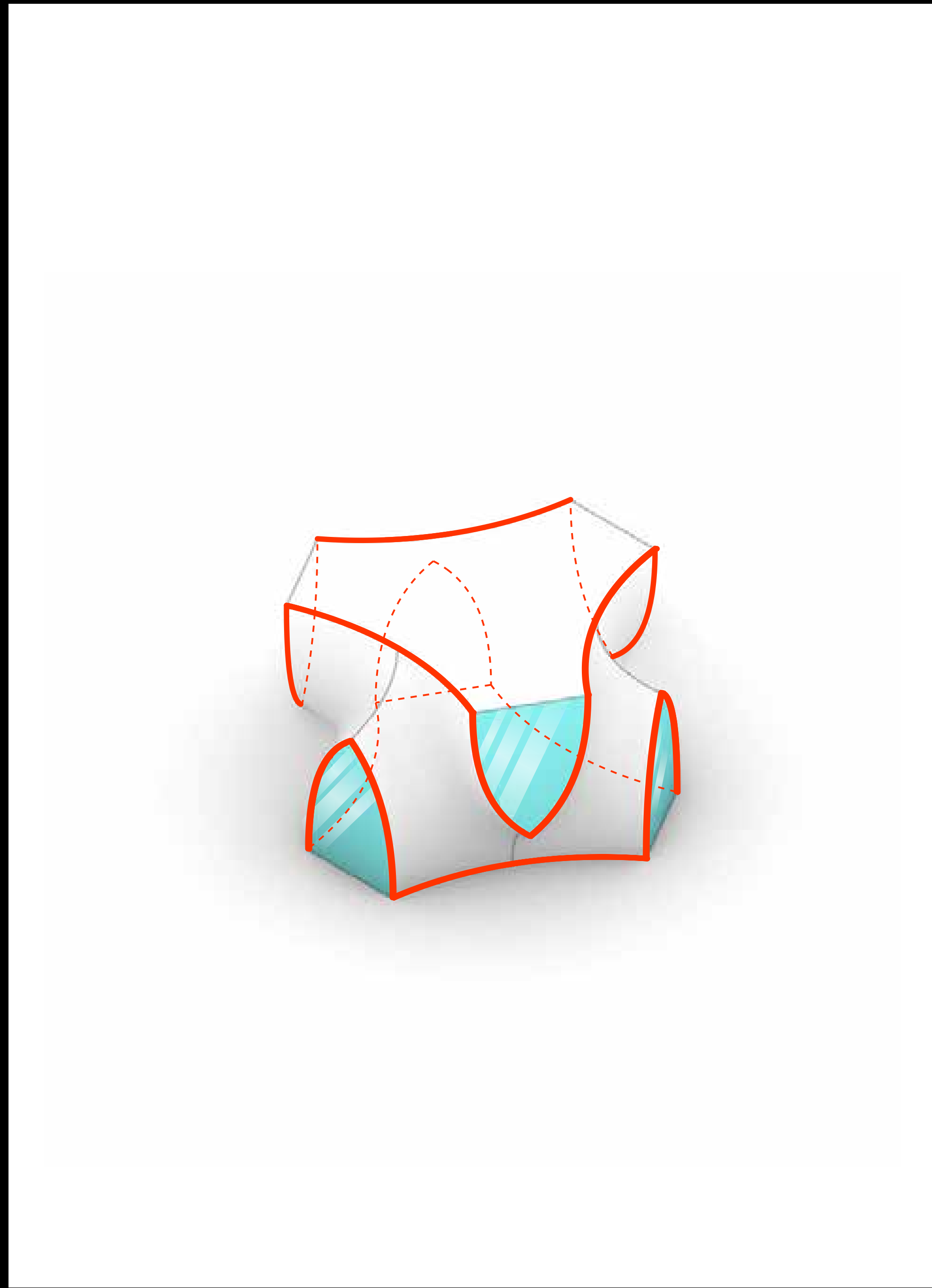
FAÇADE PLAY



BALCONY

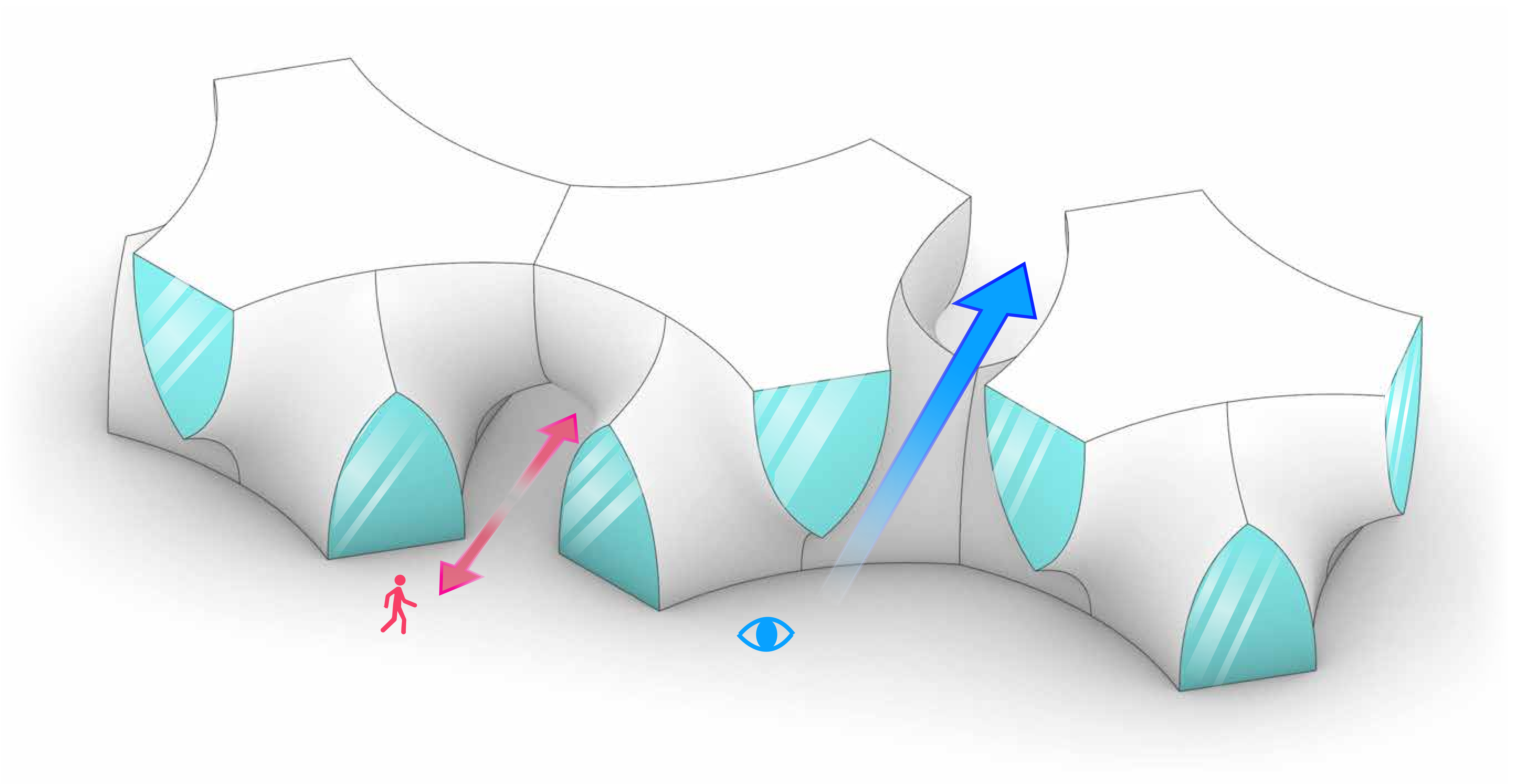


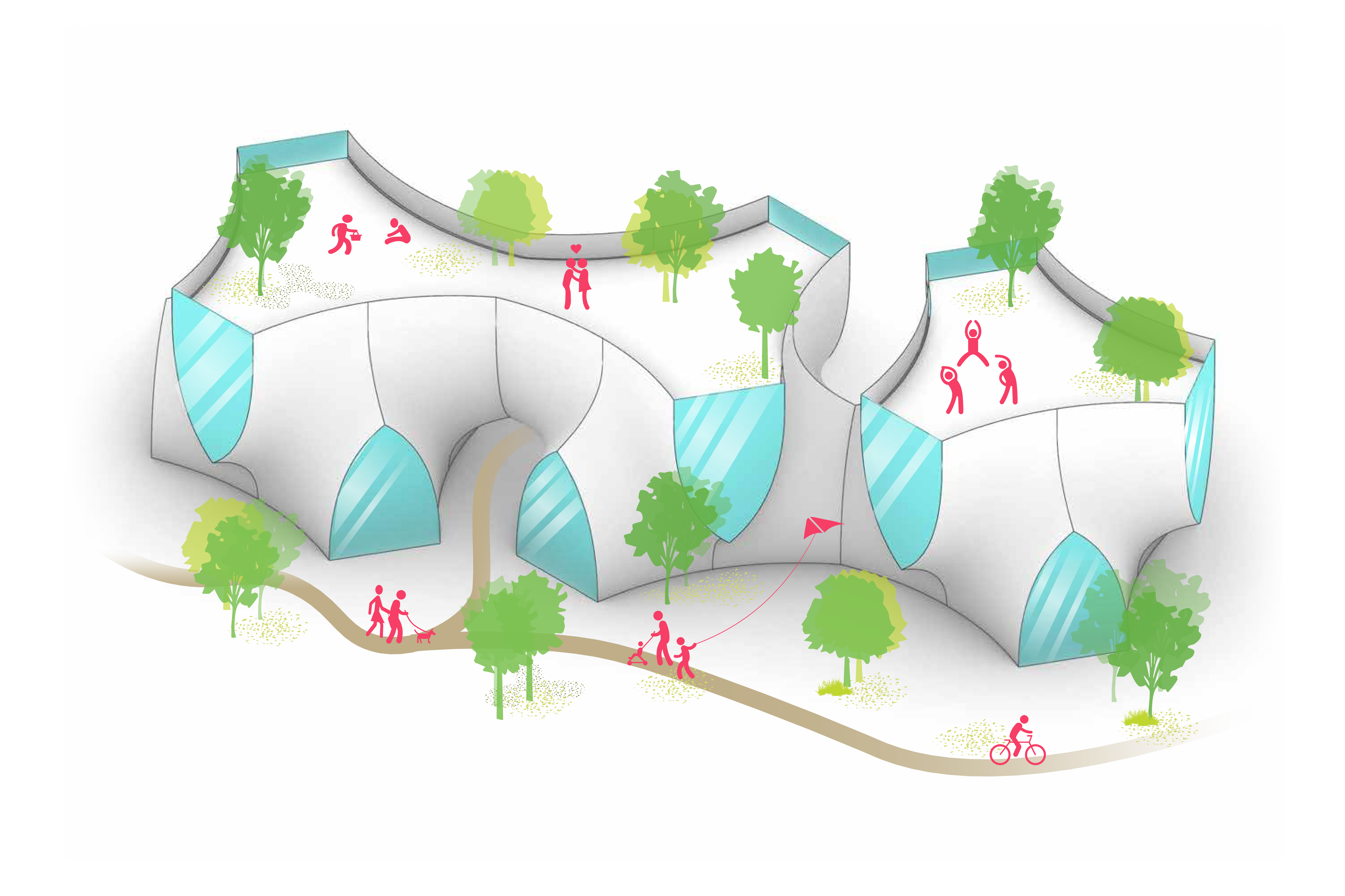
CURVED WALLS



SHELL

UNIT

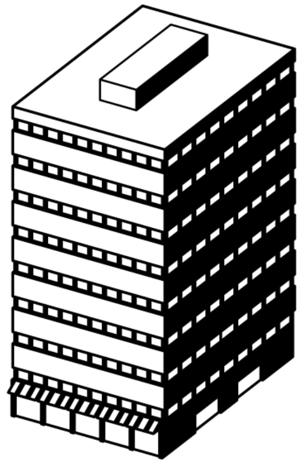




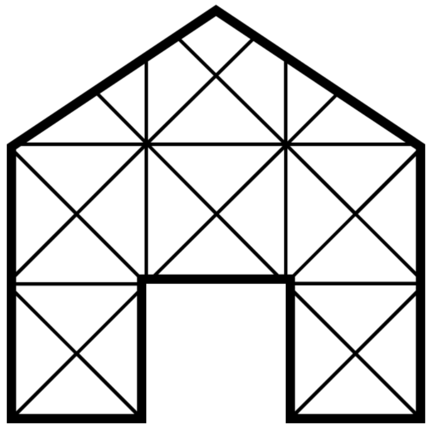
Henning
Larsen

Additive Manufacturing within three different areas

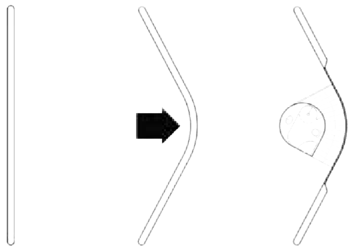
HOUSING



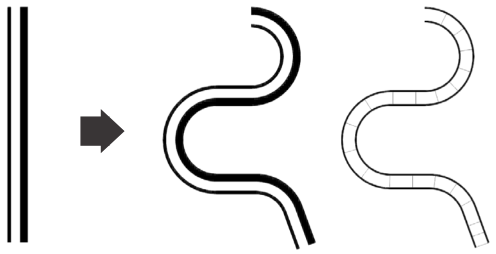
PUBLIC/COMERCIAL



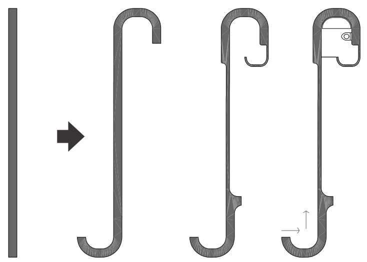
STRUCTURAL/ ELEMENTS



PROCESSES 01



PROCESSES 02



PROCESSES 03

On site Typology Optimization & Modular systems

HOUSING

Row house Typology - Housing

Row house Studies Interior Section

Row house Studies Exterior

ELEMENTS & STRUCTURAL

Staircase study Row house Typology

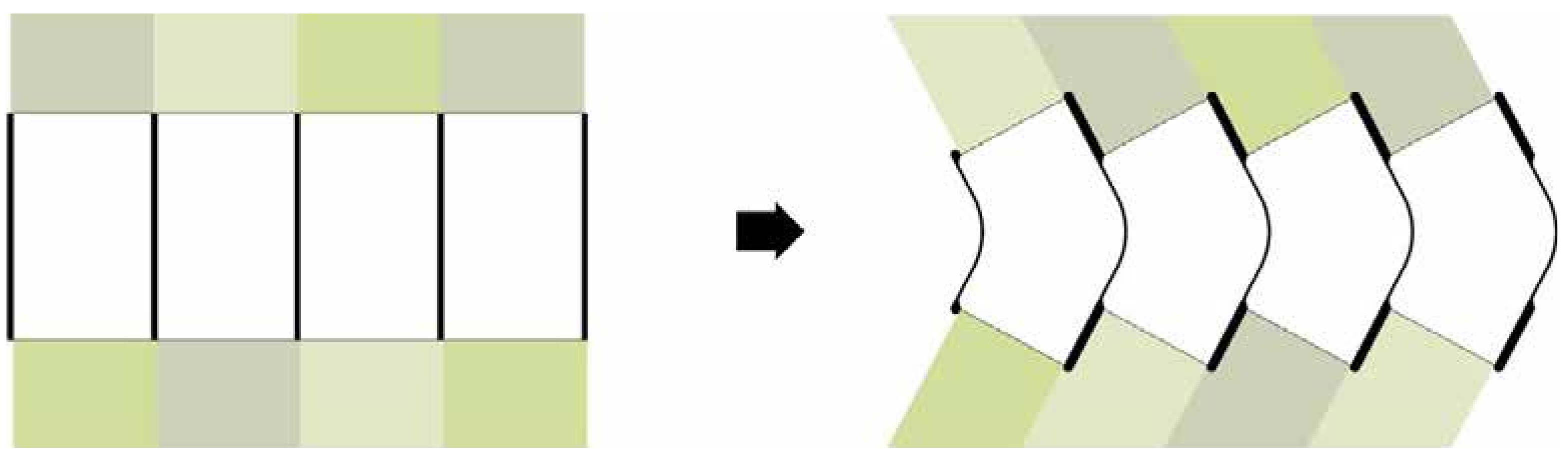
Staircase study Row house typology

PUBLIC/COMERCIAL

Large Scale production Facility

3D Printed Row Houses - Denmark

CHALLENGING THE CONVENTIONAL ROW HOUSE TYPOLOGY



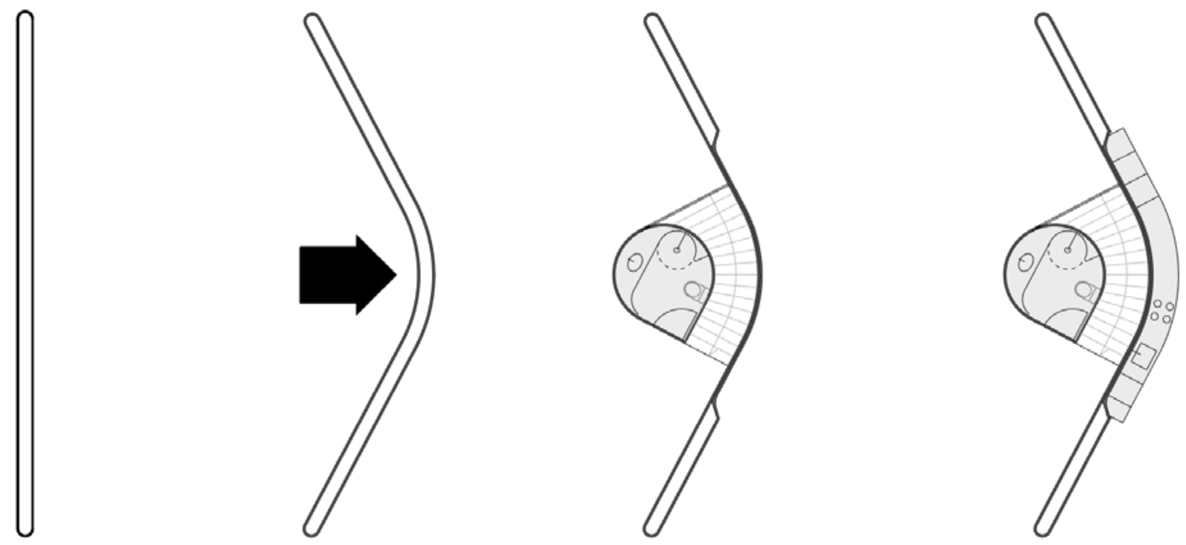


Diagram & Plan & Axo - Explanatory Drawings

From conventional row house typology to a new one

Diagram & Plan & Axo - Explanatory Drawings


36

3D Printed Row Houses - Denmark

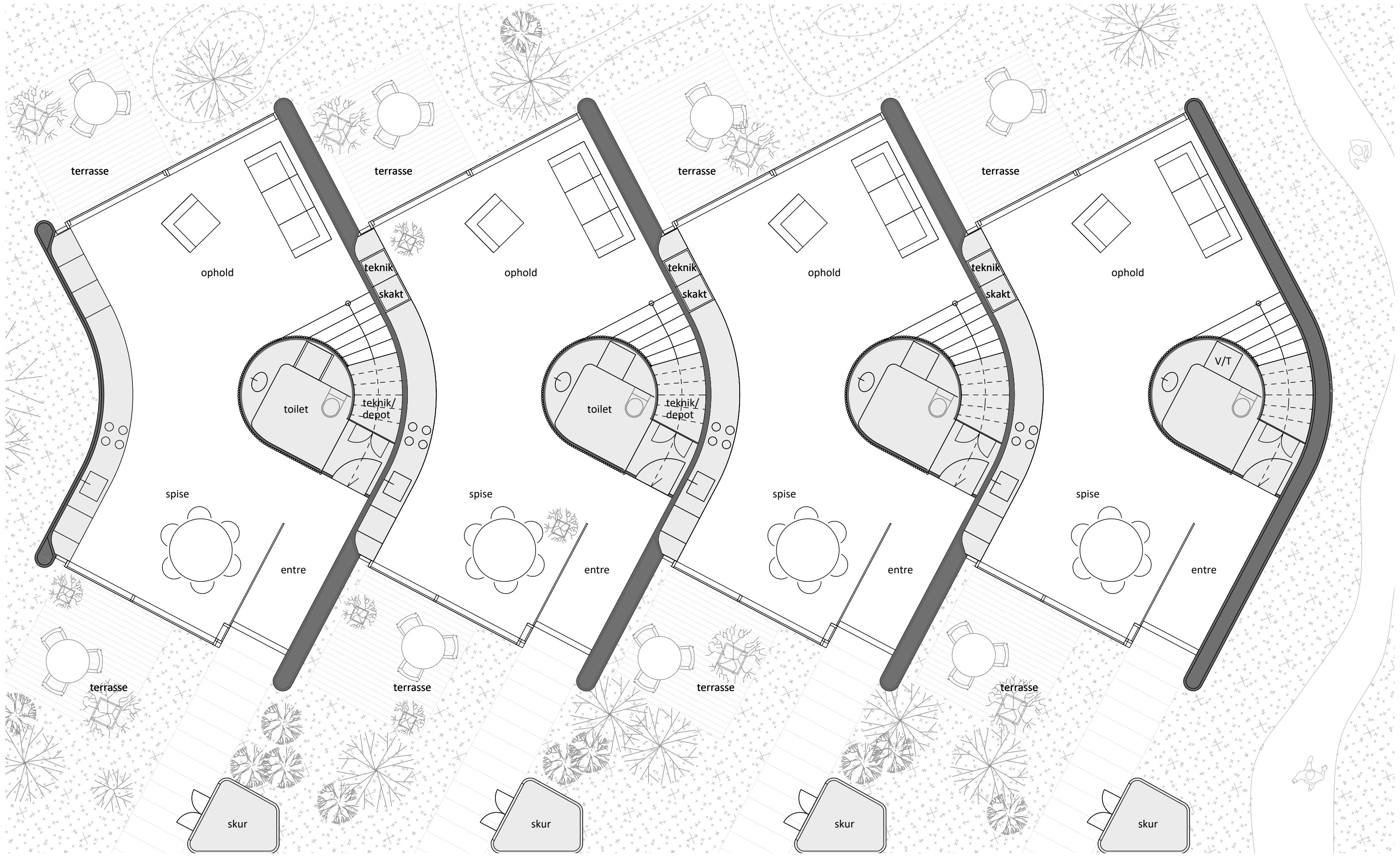


Diagram & Plan & Axo - Explanatory Drawings

3D Printed Row Houses - Denmark

3D Printed Row Houses - Denmark

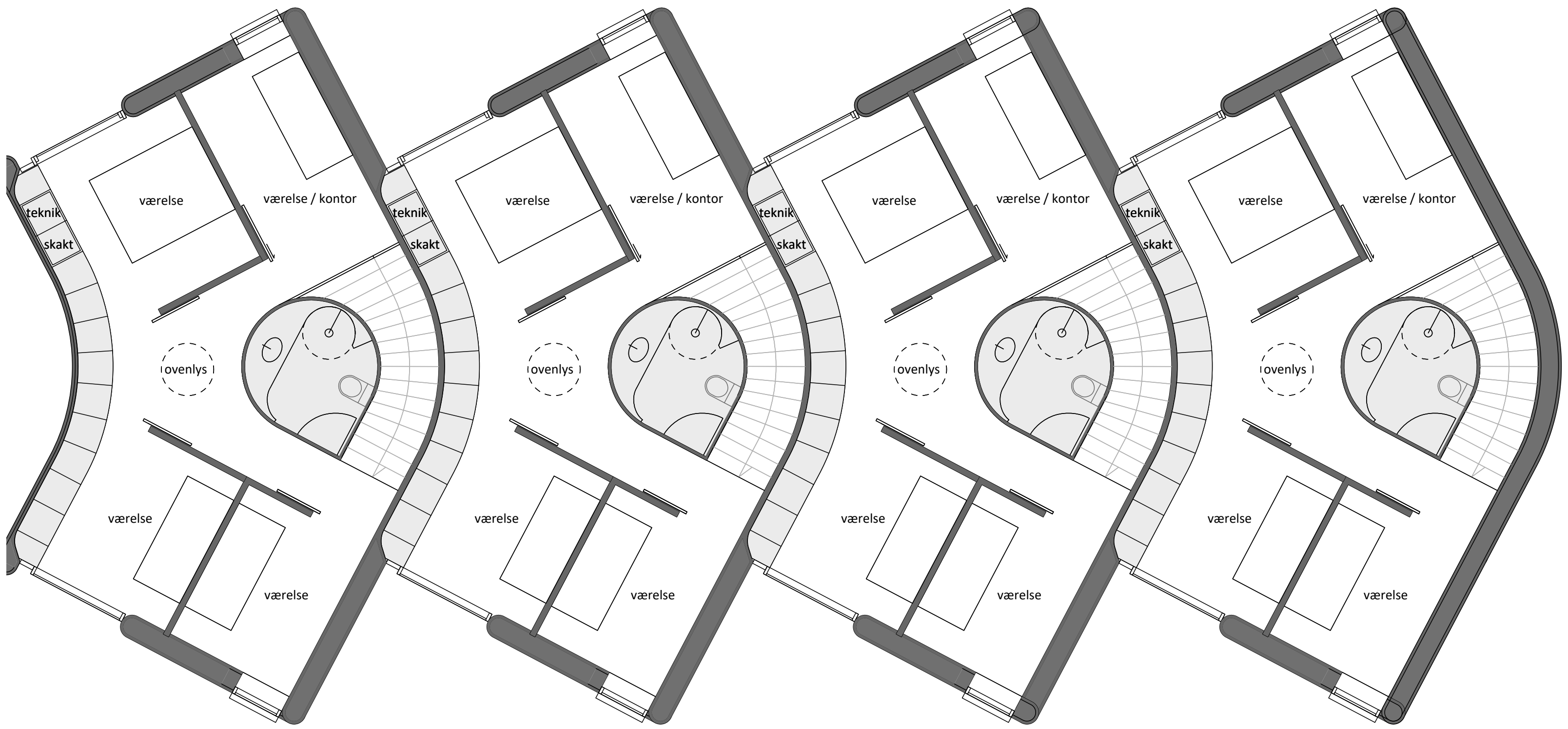


Diagram & Plan & Axo - Explanatory Drawings

3D Printed Row Houses - Denmark

Option 02

Option 01

Option 03

Option 03 - Back view

3D Printed Row Houses - Denmark / Studies

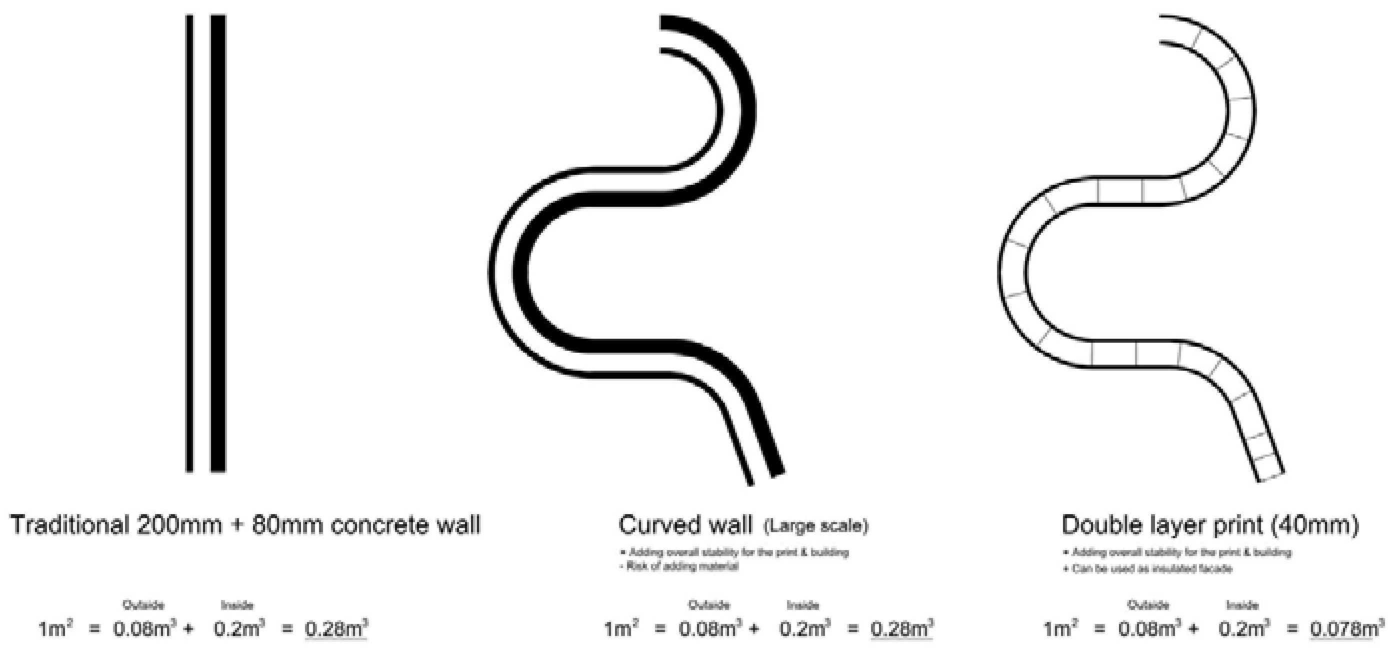


Diagram & Plan & Axo - Explanatory Drawings

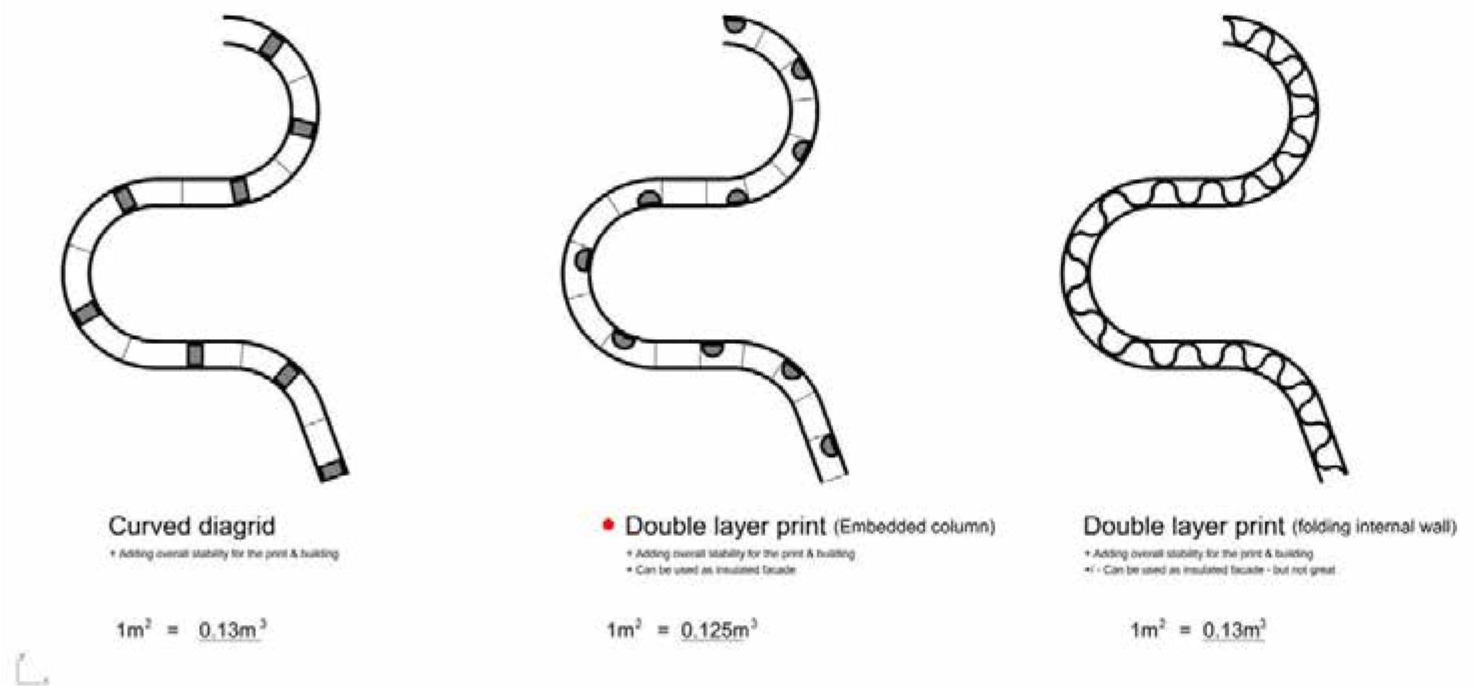


Diagram & Plan & Axo - Explanatory Drawings

3D Printed Row Houses - Denmark / Studies

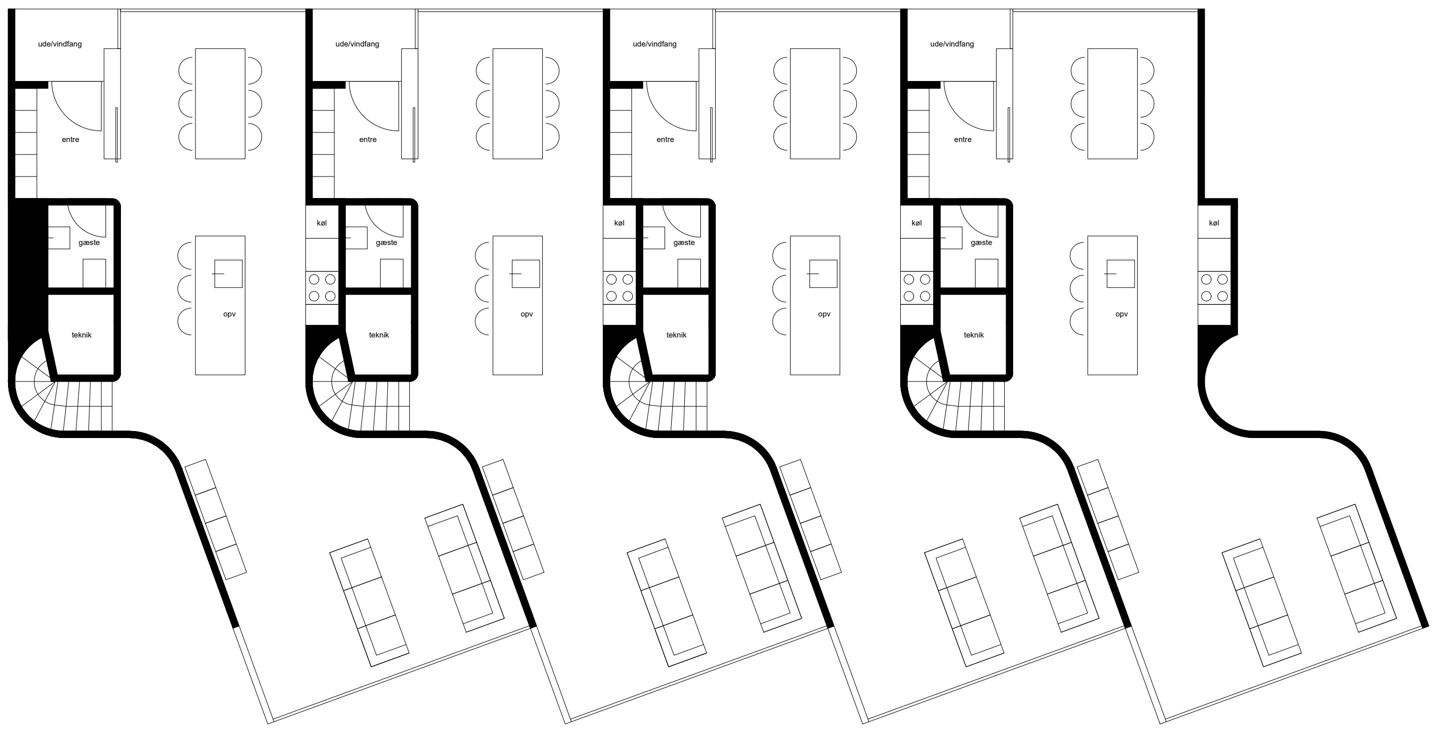


Diagram & Plan & Axo - Explanatory Drawings

3D Printed Row Houses - Denmark / Studies

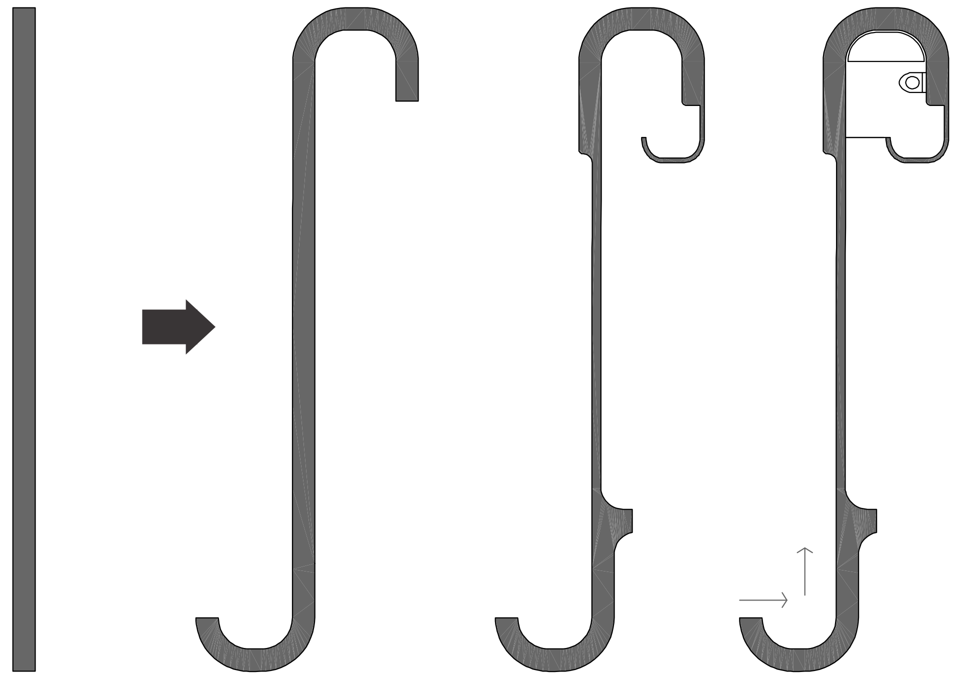
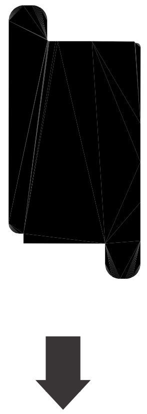


Diagram & Plan & Axo - Explanatory Drawings

3D Printed Row Houses - Denmark / Studies



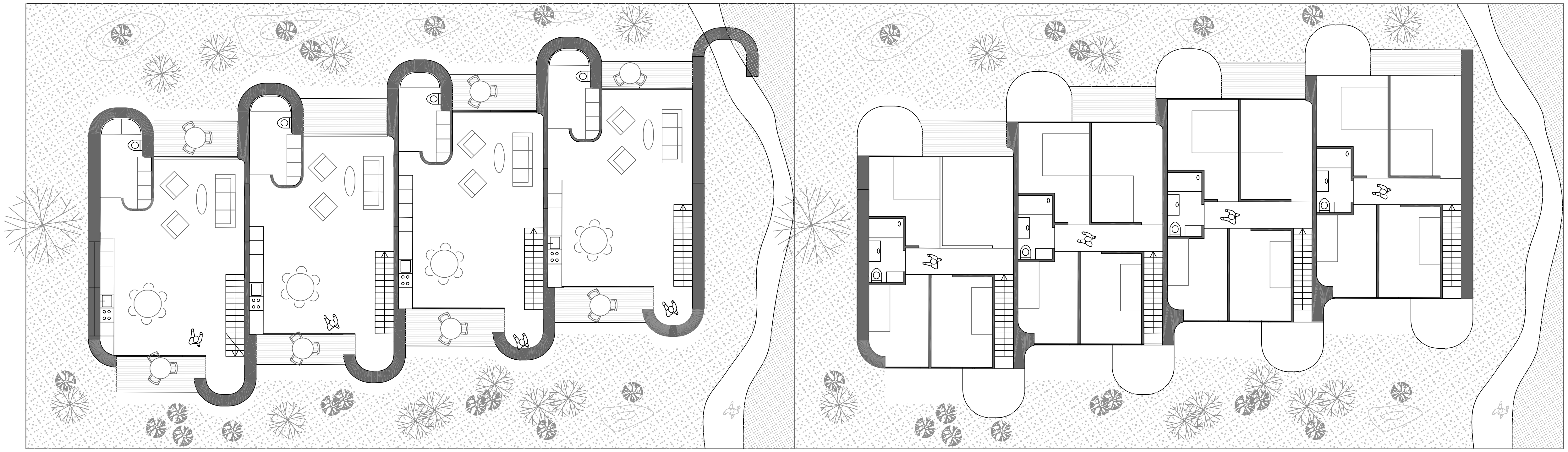


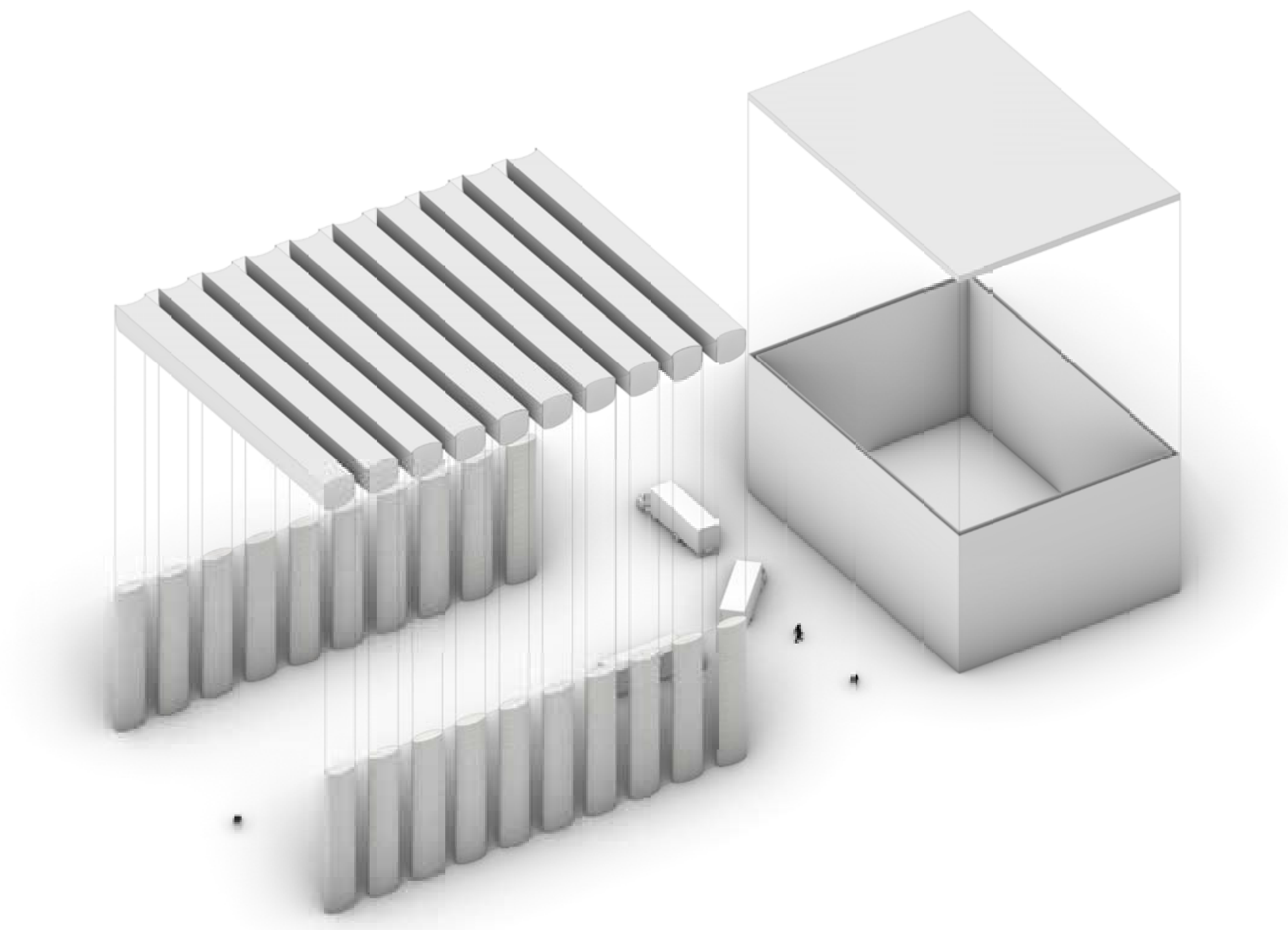
Diagram & Plan & Axo - Explanatory Drawings

3D Printed Row Houses - Denmark / Studies

3DPrinted Row Houses - Denmark / Studies

Large Scale Production - Odense Havn

WHERE PRODUCTION FACILITIES MEET INOVATION AND 3D PRINTING

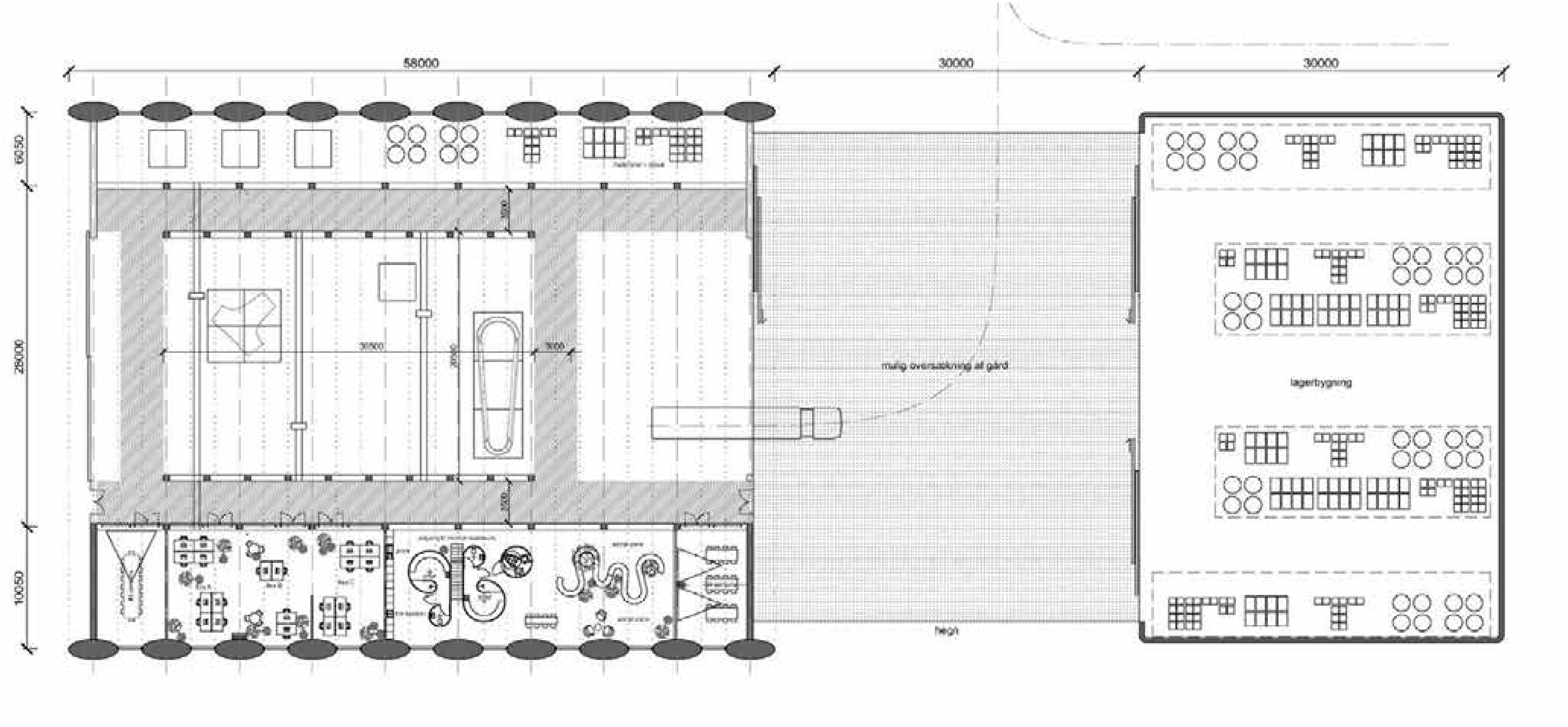


Large Scale Production Facility

Large Scale Production - Odense Havn

WHERE PRODUCTION FACILITIES MEET INOVATION AND 3D PRINTING

Large Scale Production - Odense Havn



Large Scale Production Facility - Odense Havn

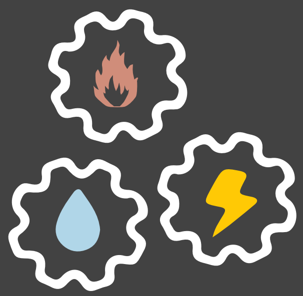
Large Scale Production Facility - Odense Havn Office Space

Large Scale Production Facility - Odense Havn Production Area

06

OFF-SITE PRINT

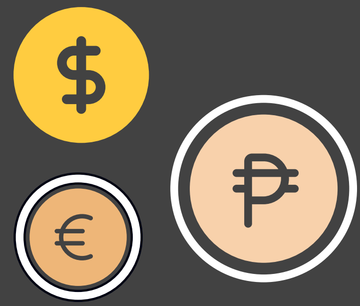
Concrete as a Material



Concrete is well known for its attributes of **strength, durability, resilience and safety**

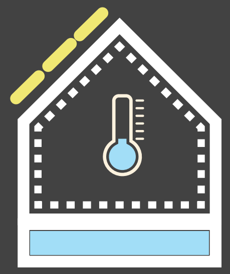
Concrete can be hence poured into various formworks or shuttering configurations to form desired shapes and sizes.

Concrete Buildings' Lifespan is around **50-80 years**



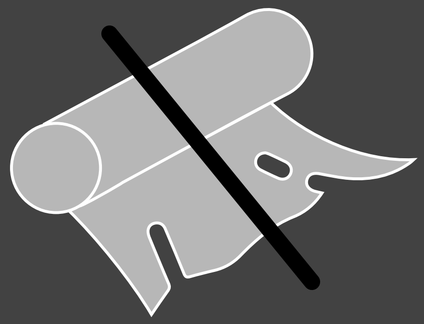
The up-front cost to build with concrete is higher than that of wood or steel. However, concrete structures substantially benefit from **reduction in energy costs** over time.

The amount of energy required for production of concrete is low compared with steel.

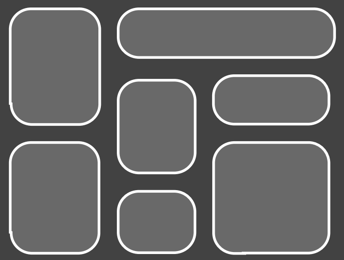


THERMAL MASSING
Lower energy consumption

LOCAL AVAILABILITY
Significant **carbon savings** in transportation.



DIFFUSION-OPEN
Better Inner environment and **no plastic**

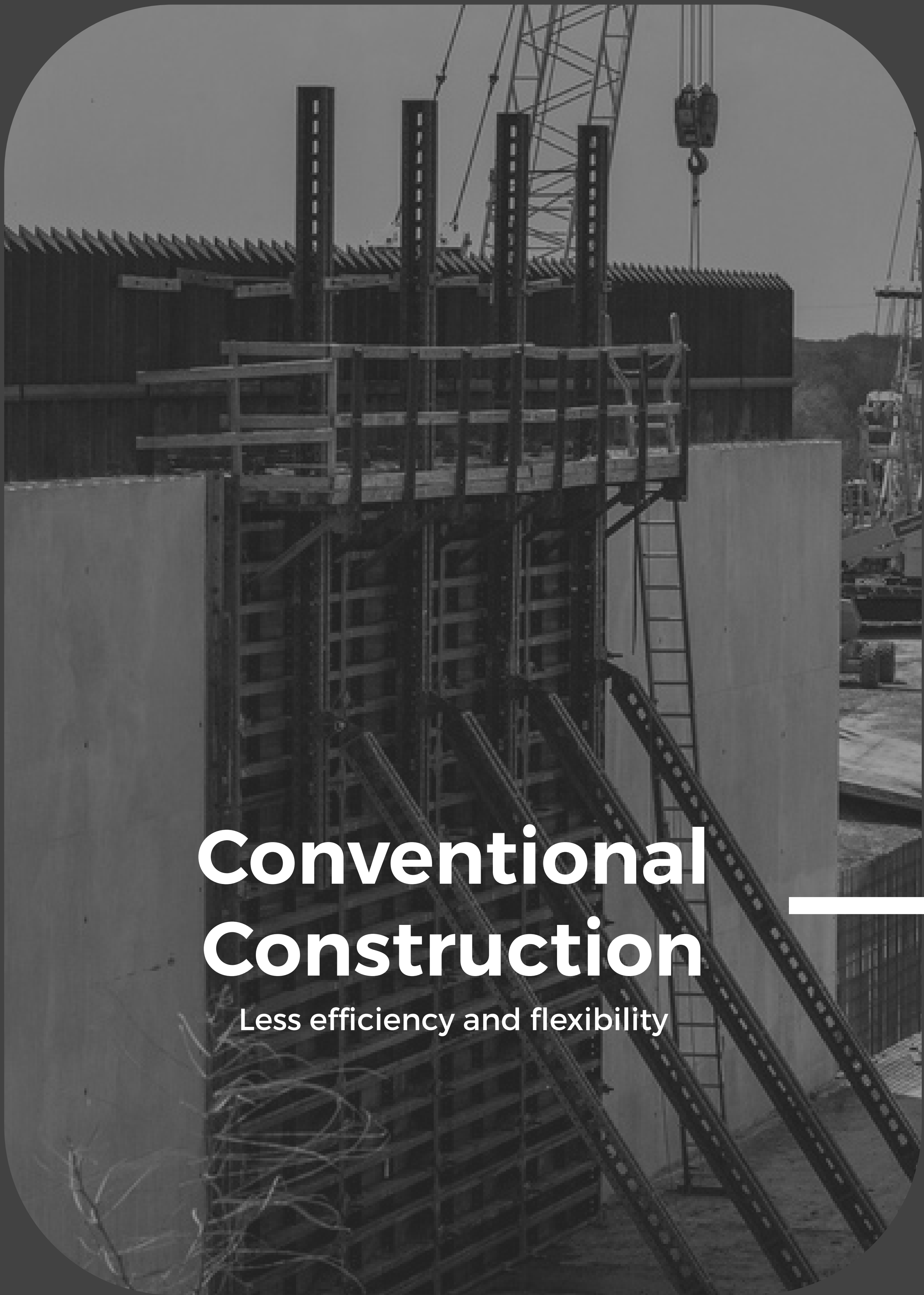


STEEL REDUCTION DESIGN
Reduced use of raw materials and reduced **waste**

RECYLCING AND REUSING
Reduced construction costs and environmentally friendly

When taking the performance of a building over its whole lifecycle into account, concrete offers significant sustainability benefits over other building materials thanks to its innate properties, such as its durability, resilience, its thermal mass, its recyclability, its carbon uptake and its local availability.

CONCRETE AS A SUSTAINABLE MATERIAL



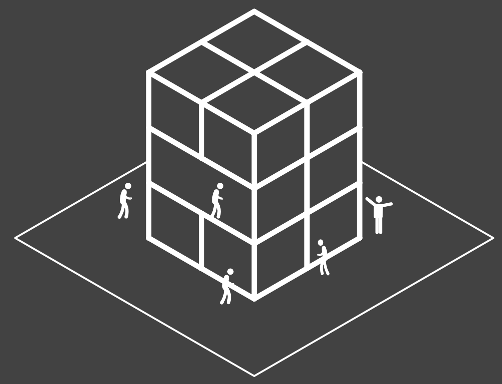
Conventional Construction

Less efficiency and flexibility

3D Printing

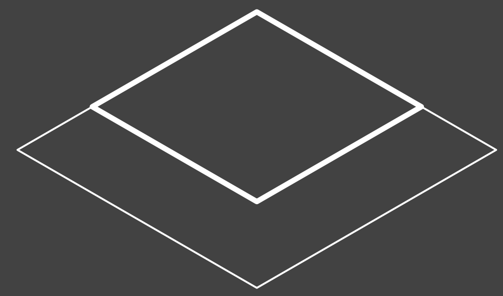
Optimized efficiency and sustainability

TRADITIONAL CONSTRUCTION

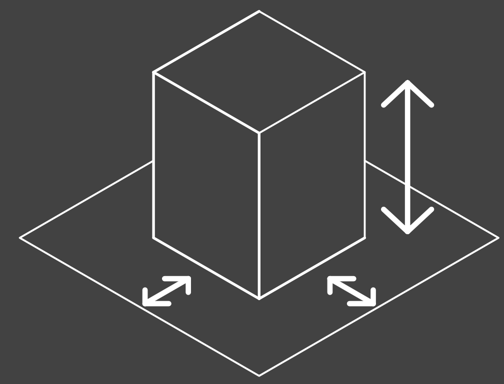


Pysical Labor

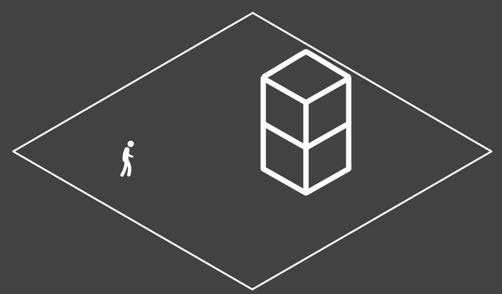
Material waste



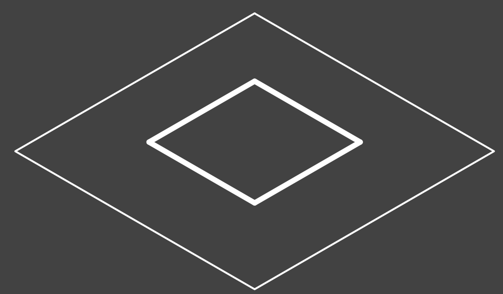
Permanent and limited life span



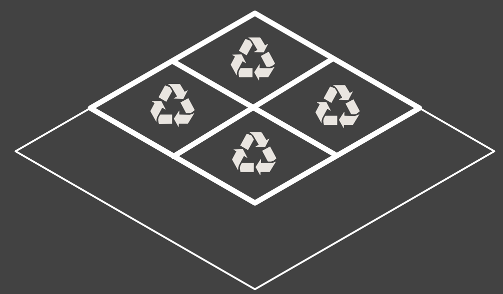
Constrained and non-flexible design



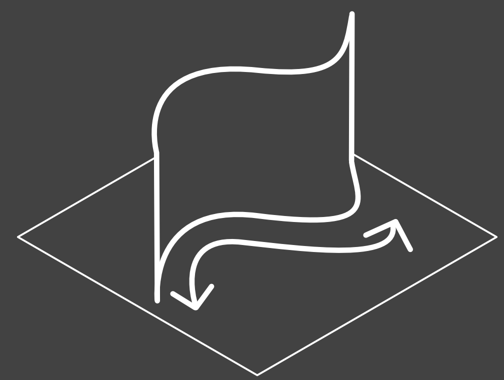
Decrease in physical labor



Material Efficiency



Reusability

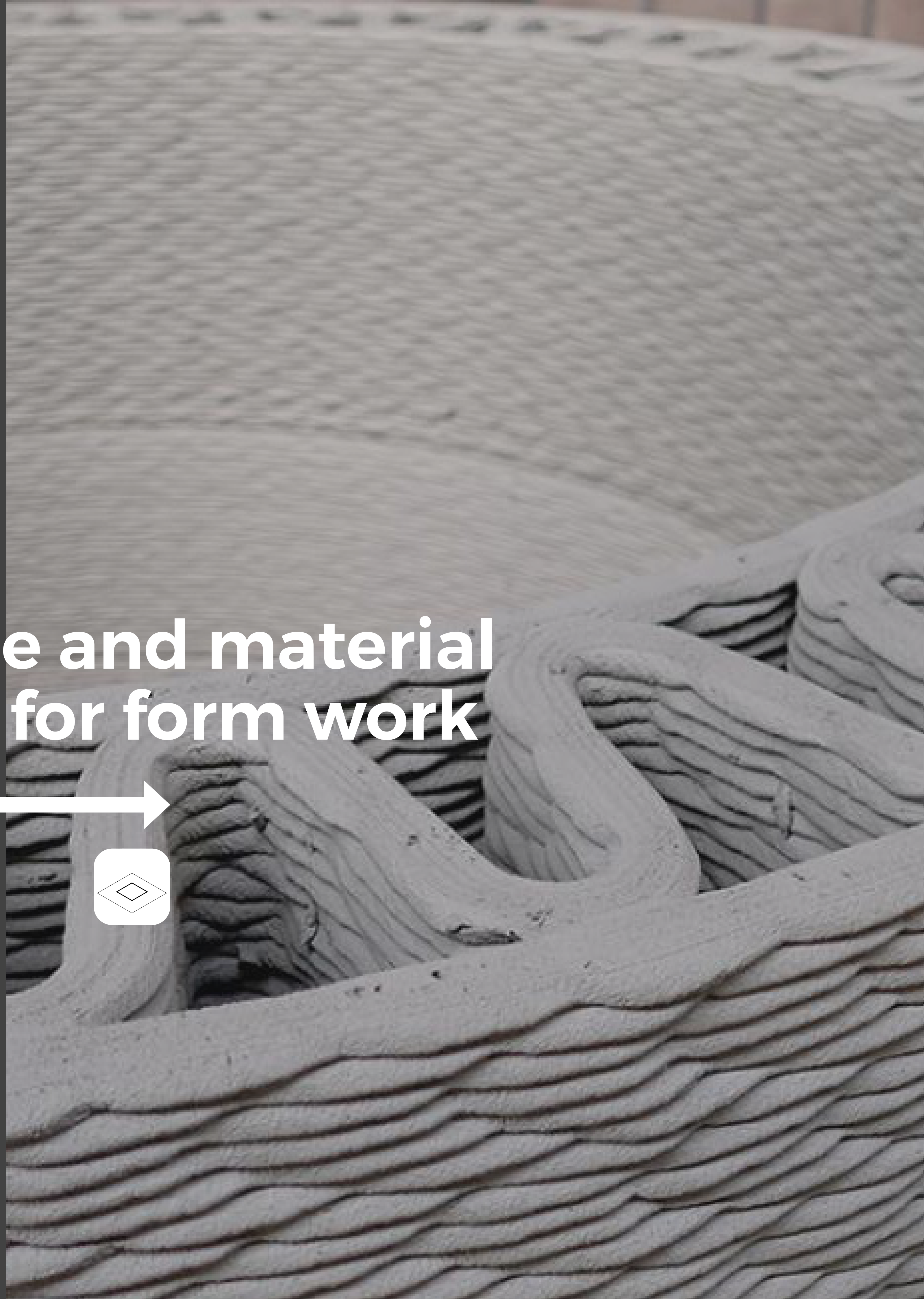


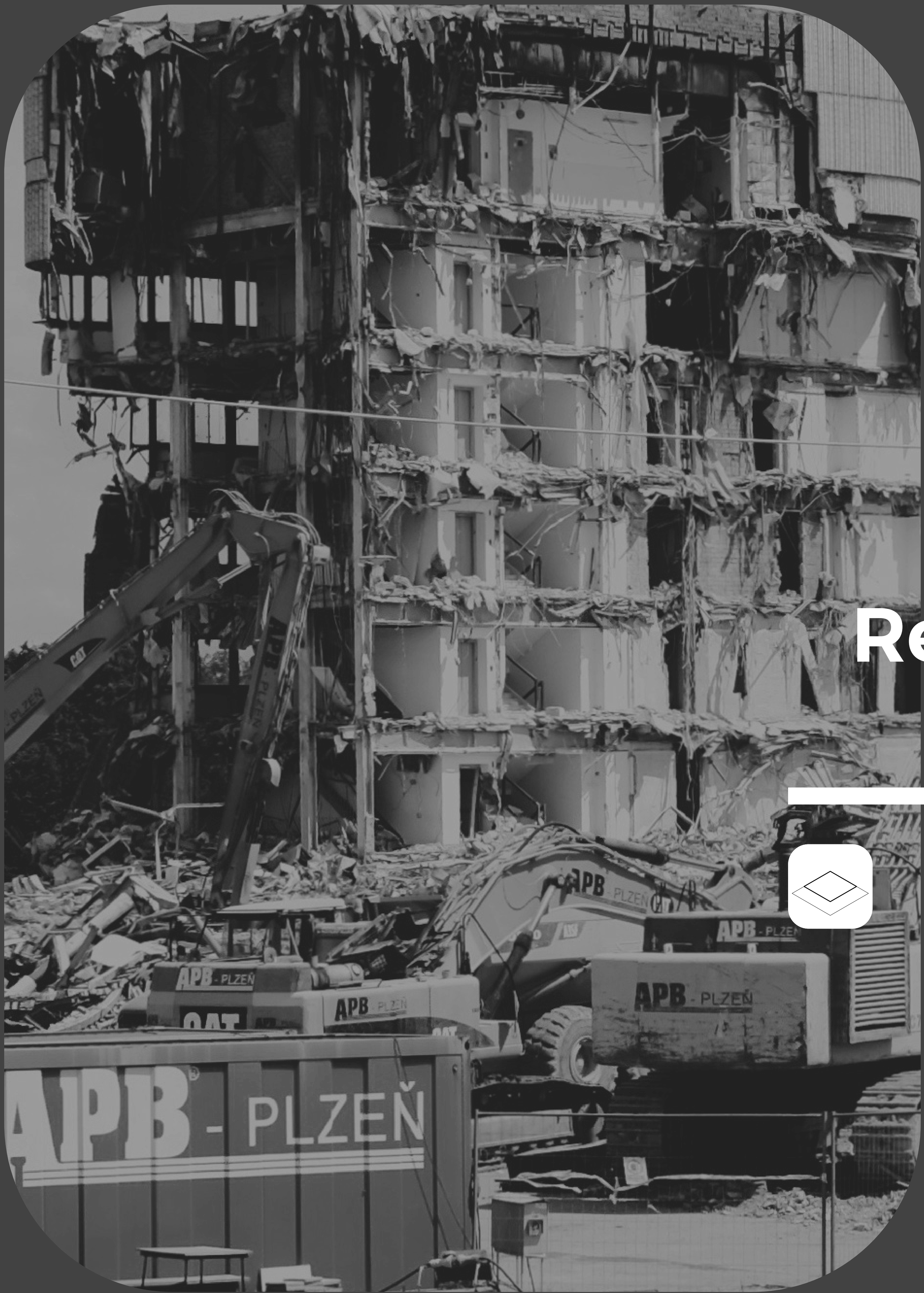
Flexibility Of Use

3D PRINTING

Decrease In Physical Labor

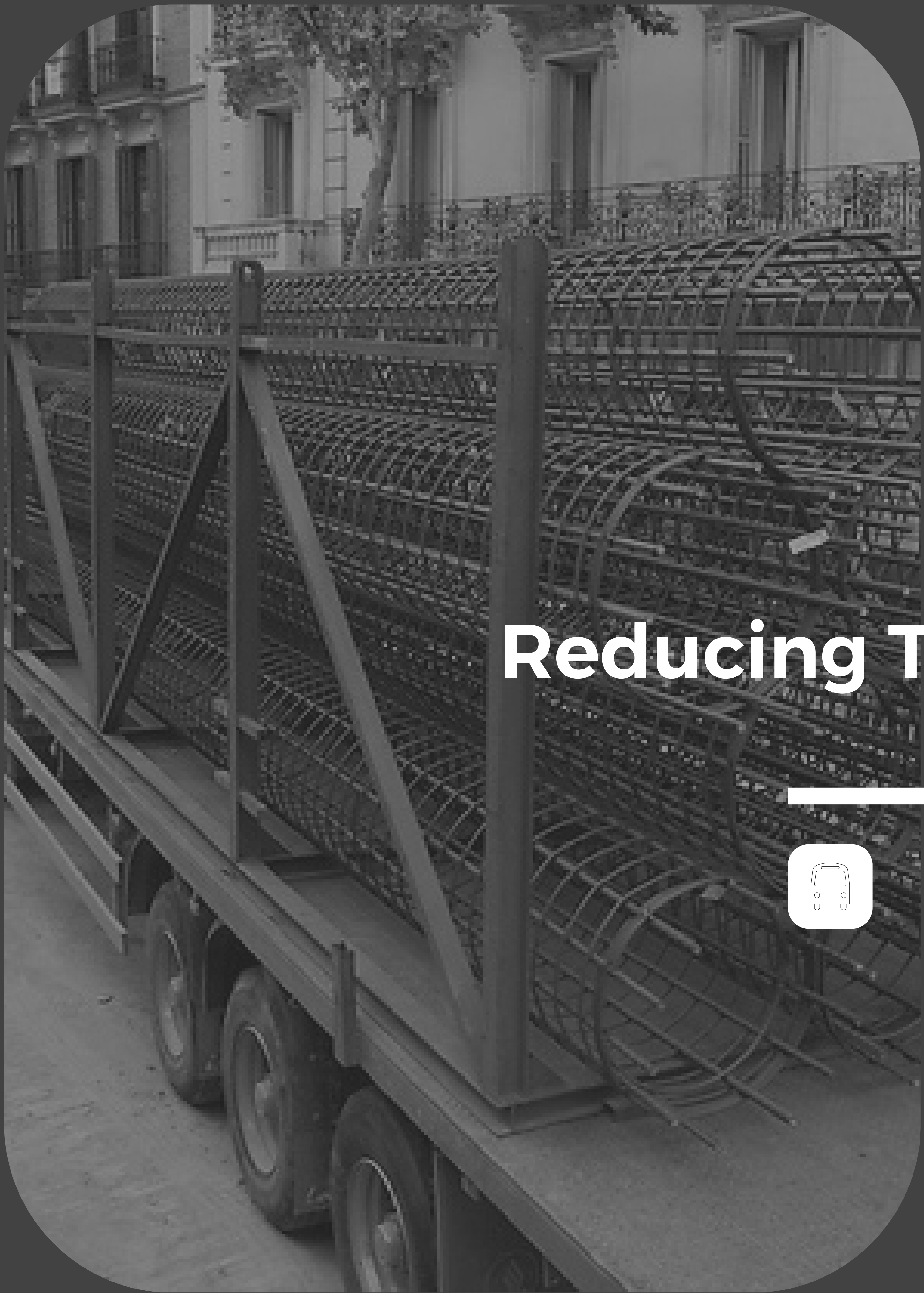
Reduced waste and material consumption for form work



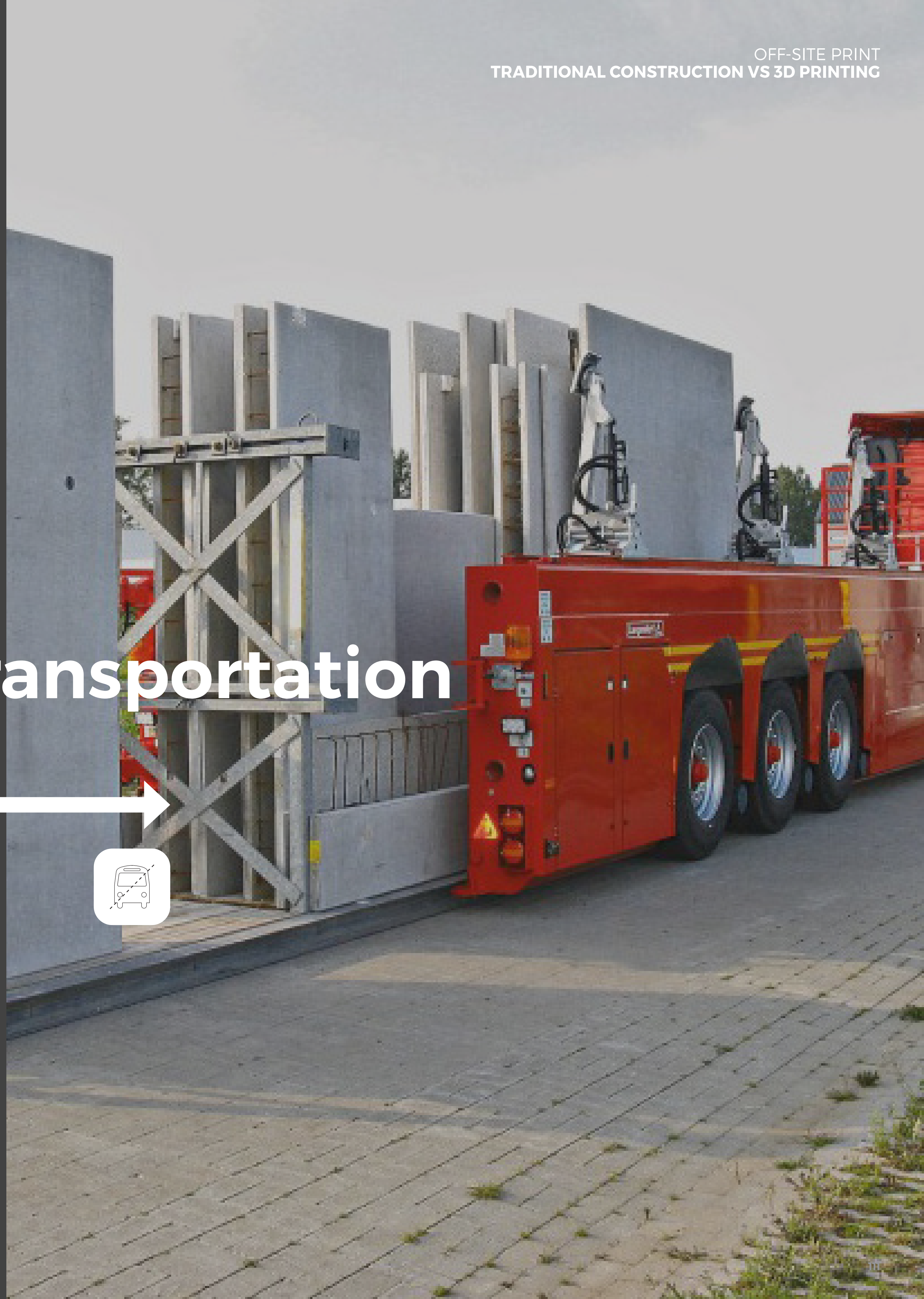


Reuse

Flexibility of Use



Reducing Transportation

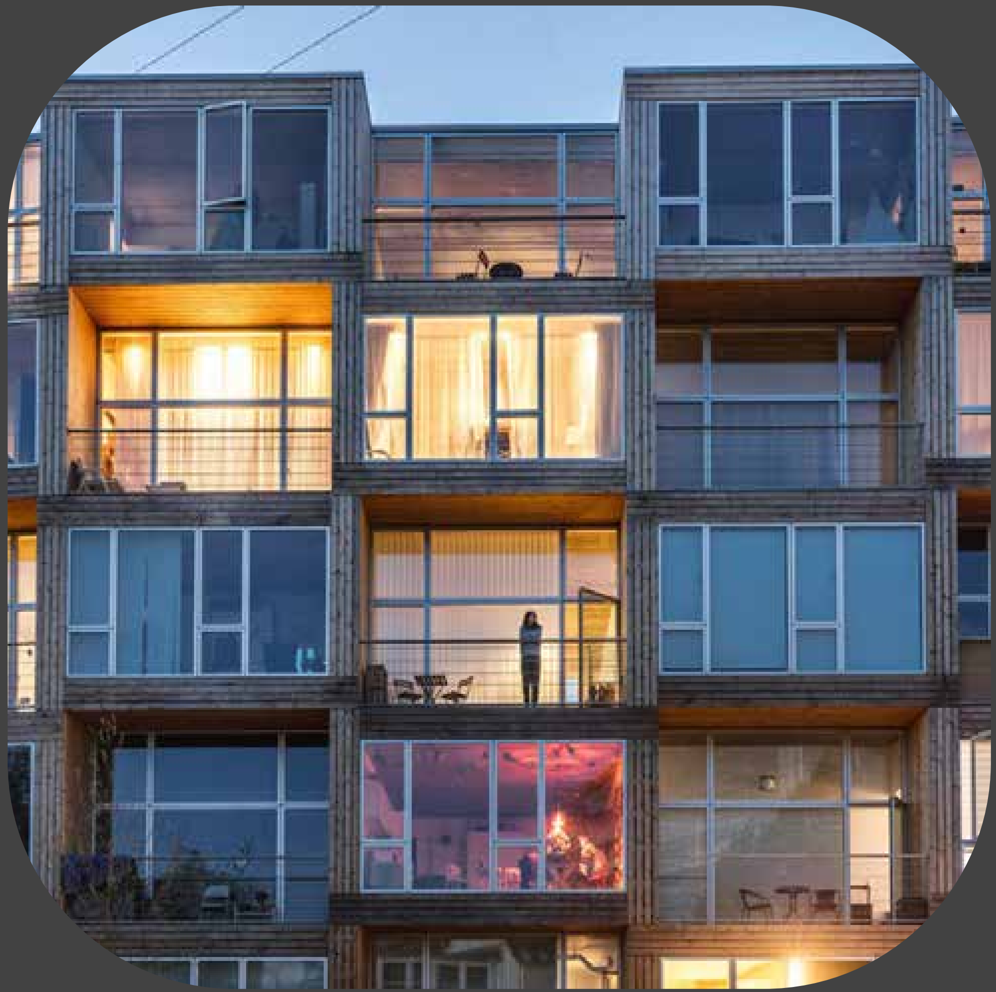


Prefabricated Elements

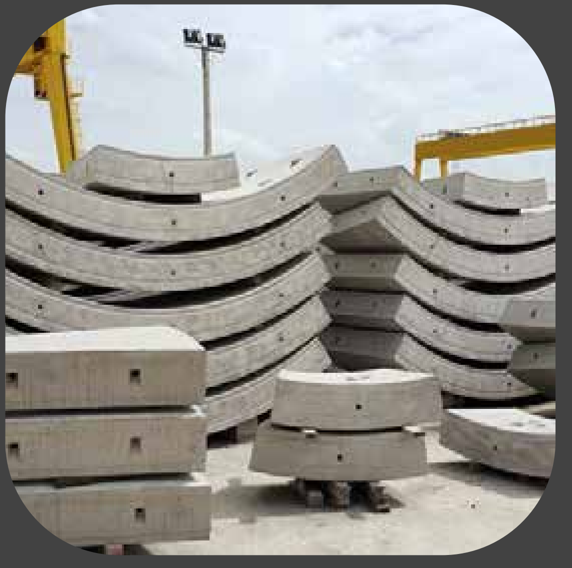
N3XTCON

N3XTCON

Modular Architecture



Prefabricated Elements



Increased Labor Efficiency Enables Personal Related **Costs to Decline**

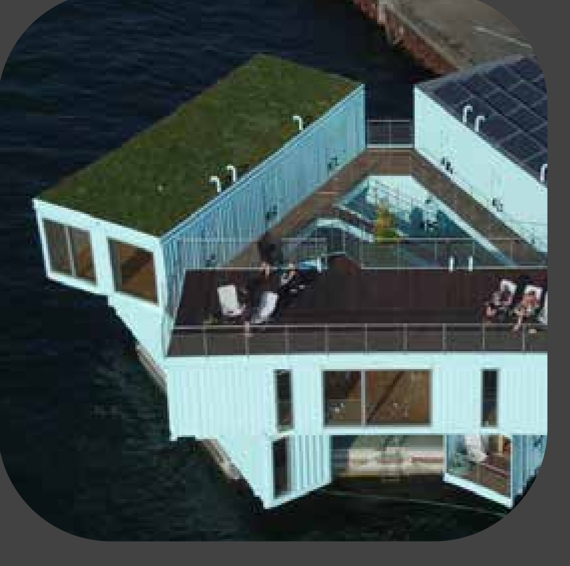
Building and the Site Work Can Be Completed Simultaneously which makes it **Time efficient**

Less **Framework**
Decreased Material Waste

Improved **Construction Quality** Due to Controlled Environment

Modular Structures

Factory Enviorement Prevents Any **Delays Caused By The Weather**



Easy and Fast to **Construct and Deconstruct**

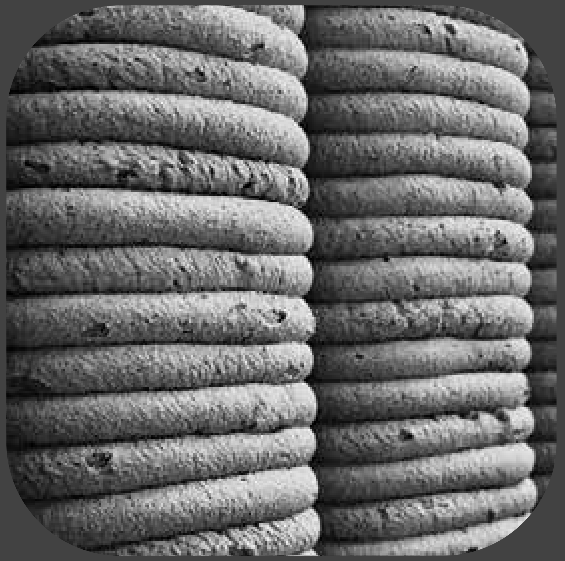
Off-site Construction Enables to Reduce **Greenhouse Gas Emissions** By 30%

Timber Frame Construction Causes **Limited Life Span**

PREFABRICATED ELEMENTS AND MODULAR CONSTRUCTION

Bespoke design process allows extreme flexibility in terms of space utilization, purpose of use and overall design.

3D printing the modules reduces the construction time and cost significantly.



The construction method is a more environmentally friendly as it encourages more **green insulation materials** and reduces the amount of plastic use.

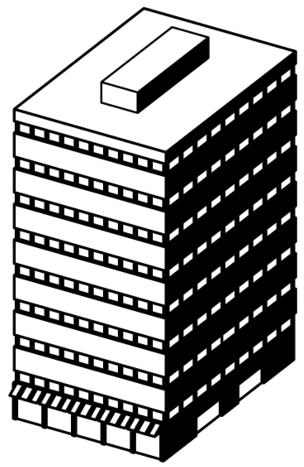
Creating **social sustainability** that support societies through changing social needs by being enabling and physically flexible.

3D PRINTED N3XTCON UNITS

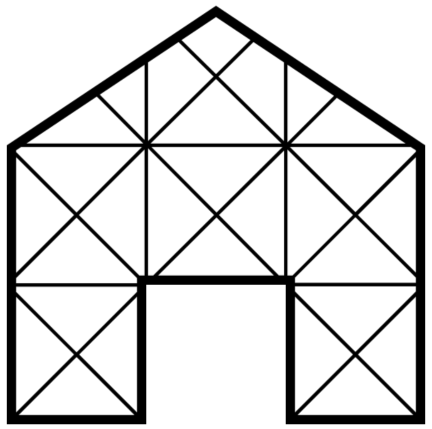
Henning
Larsen

Additive Manufacturing within three different areas

HOUSING



PUBLIC/COMERCIAL



STRUCTURAL/
ELEMENTS

Off-Site Typology Optimization & Modular systems

HOUSING

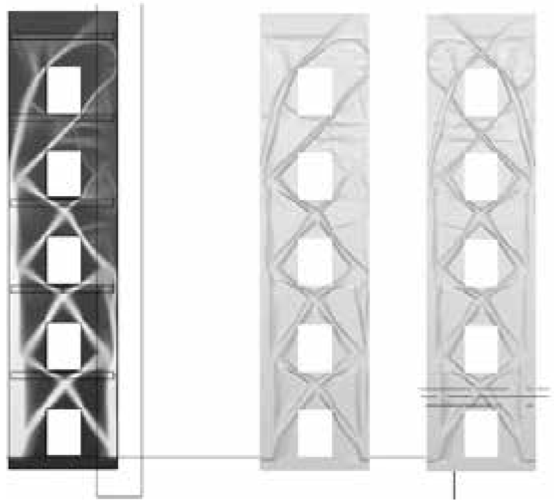
Modular System - Upside down 3d printing

Optimized module 3d printed as a whole

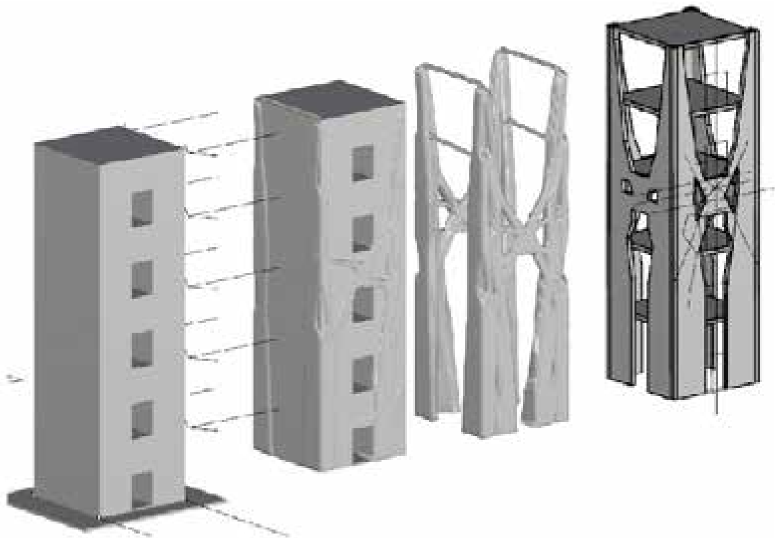
Modular expression study 01

Modular expression study 02

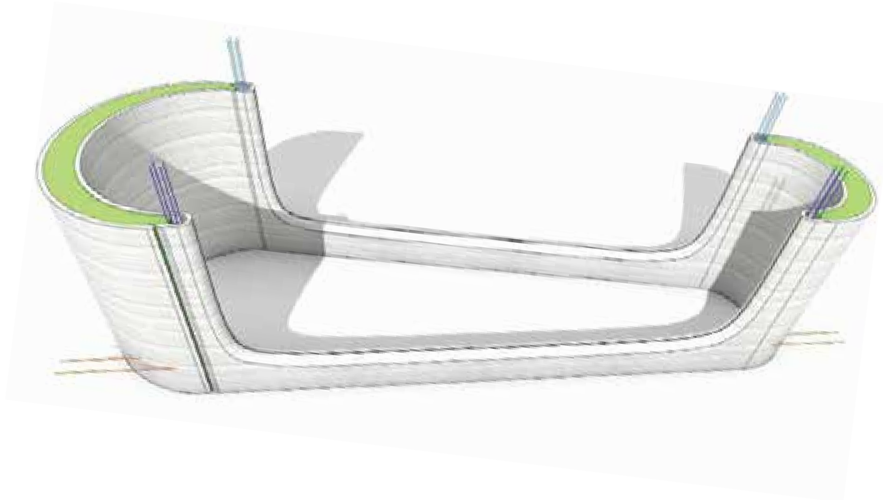
ELEMENTS & STRUCTURAL



Typology Optimization - Various Scales



Typology Optimization - Various Scales/Elements



3D Printed modular Unit - Of site

PUBLIC

3d Printed Columns - Structural Optimization Common House

Housing Project, Denmark

PROCESS EXPLANATION

This project will culminate in a prototype for a built structure showcasing the improved printing process developed during the partnership. Ultimately, our goal is to produce a full-scale 3D printing concrete building with reduced CO2 emissions.

The future impact of the N3XTCON project encompasses the highlighted UN Sustainable Development Goals.

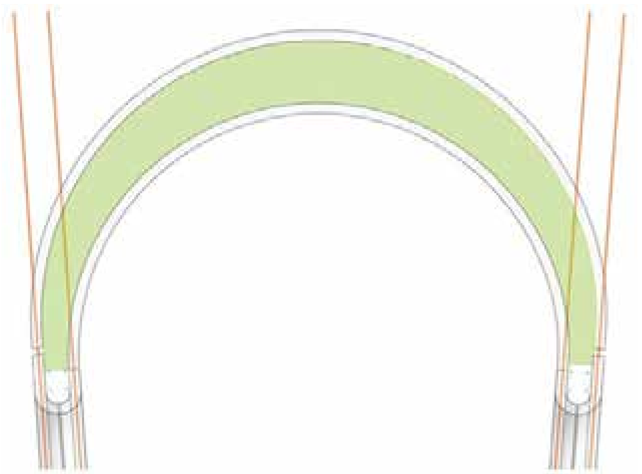


Diagram the proccess of printing

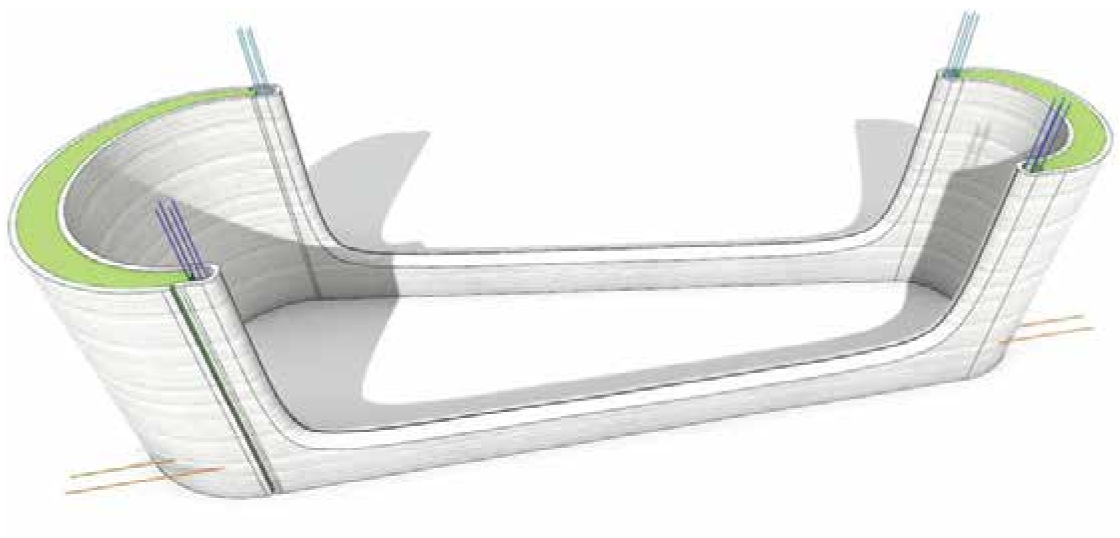


Diagram & Plan & Axo - Explanatory Drawings

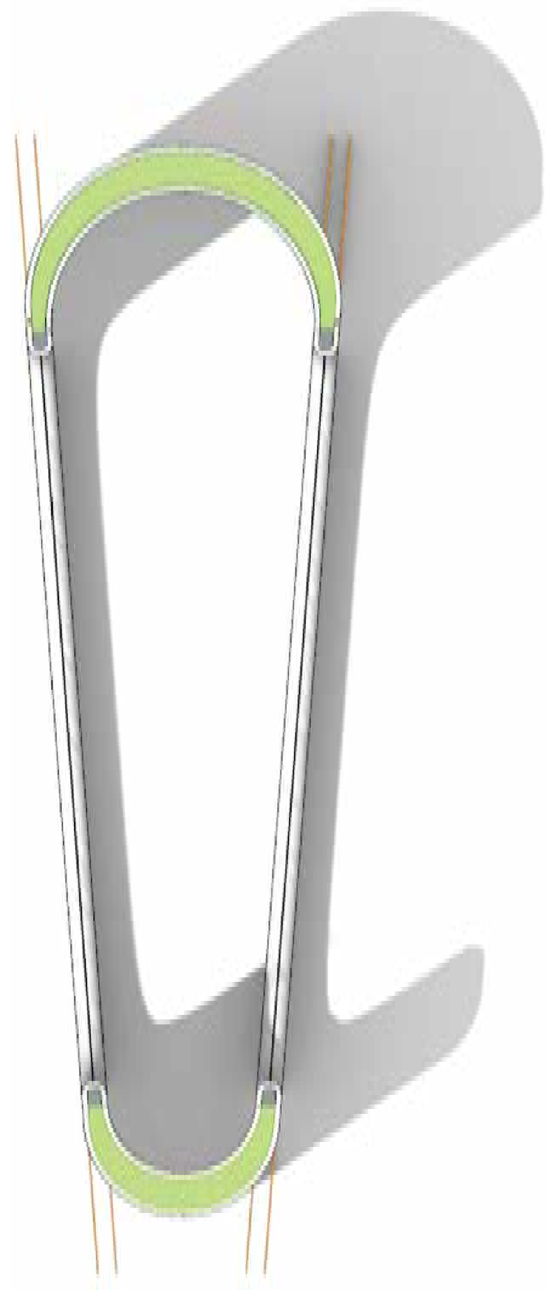
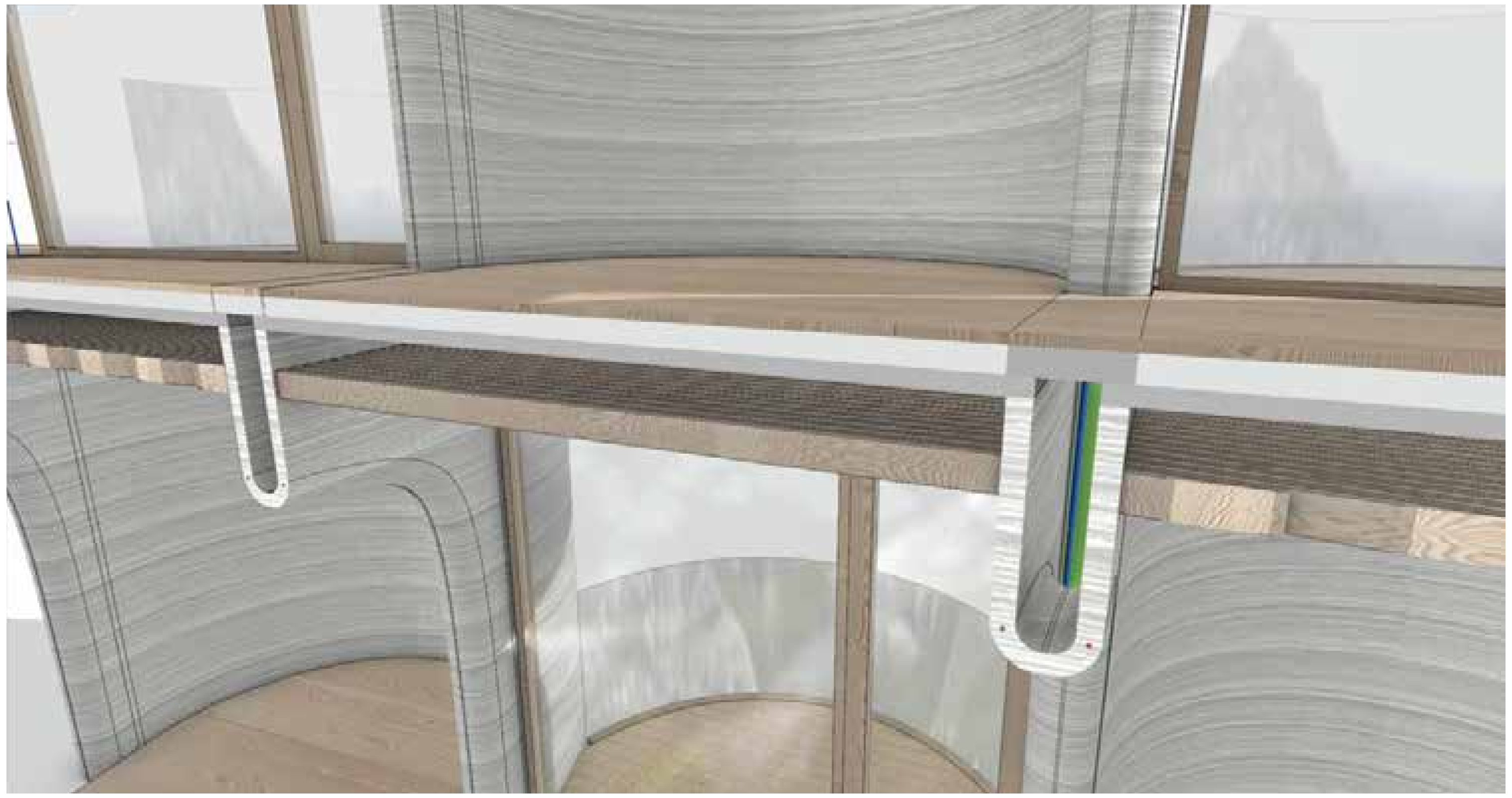


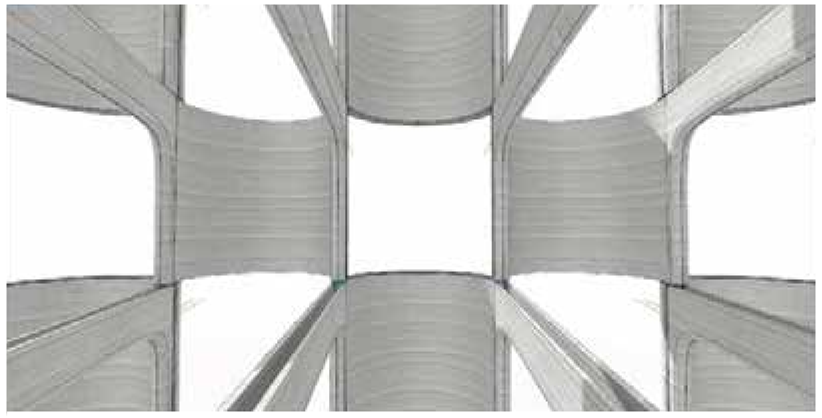
Diagram & Plan & Axo - Explanatory Drawings

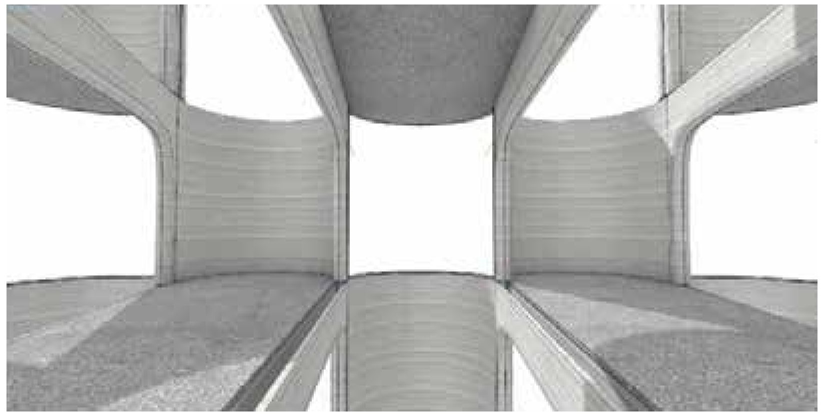
Housing Project, Denmark

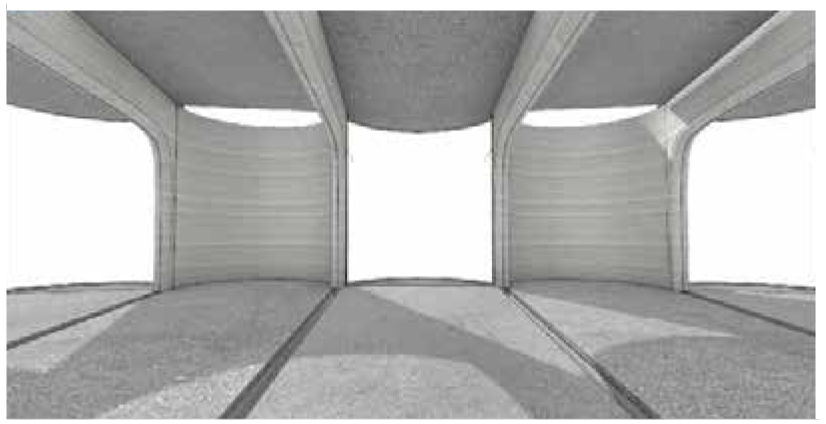
PROCESS EXPLANATION
The overall process aims to find ways to innovative while producing / 3D print modular units with all their optimal properties and assembling on site. One of the main benefits of additive manufacturing is that it allows architects and designers a great flexibility in design and creativity while being environmentally cautious while using less material.
3D printing these units of site in enclosed optimally controlled environments will substantially lower their environmental impact.

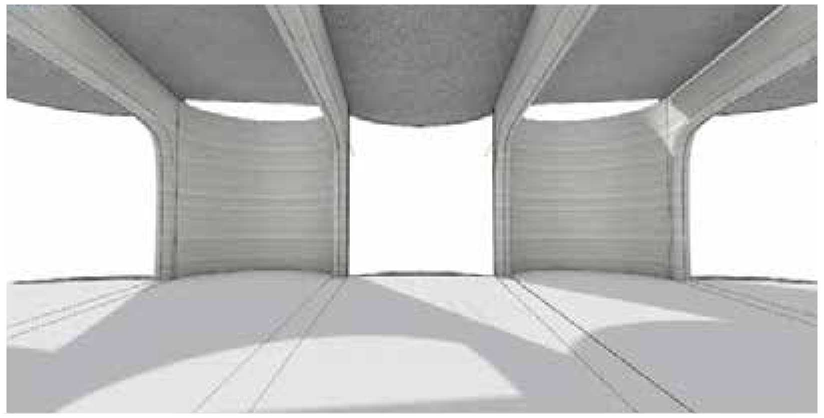


Modules interconnection technique

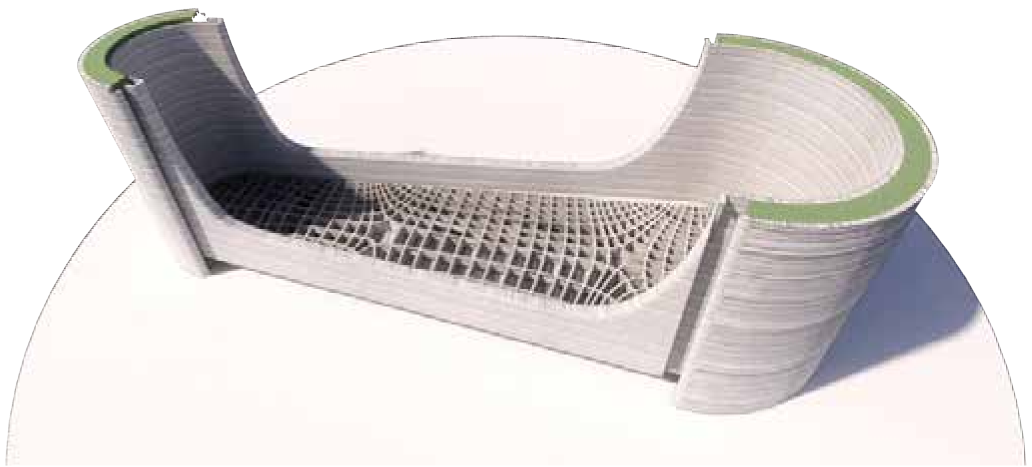




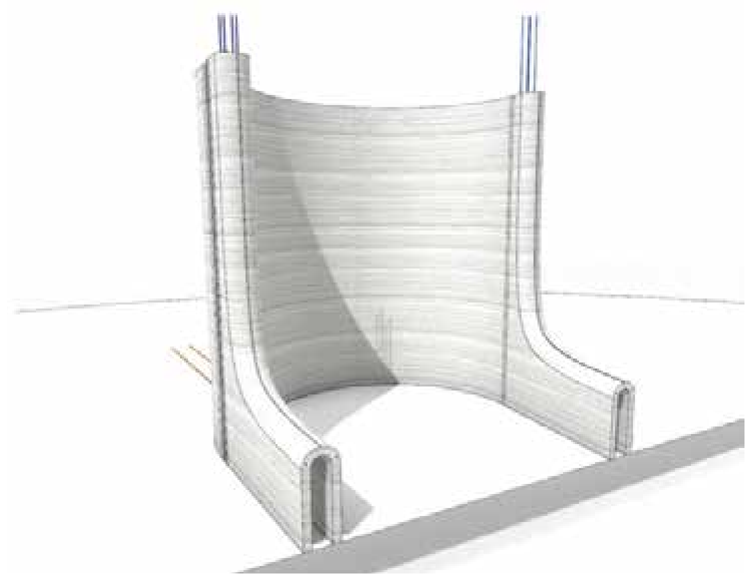




Housing Project, Denmark



Modular System 3D Printed

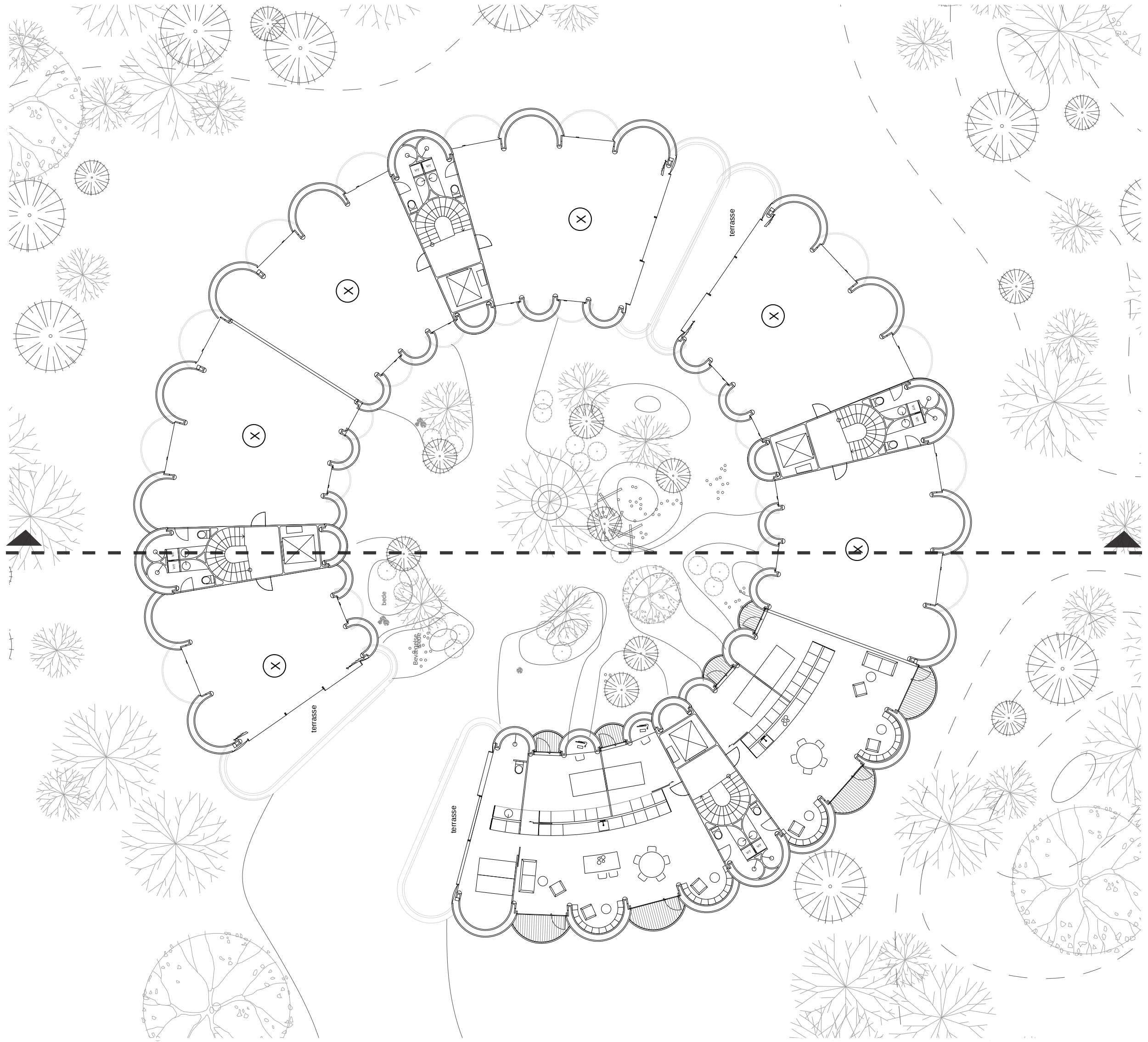


Modular System 3D Printed

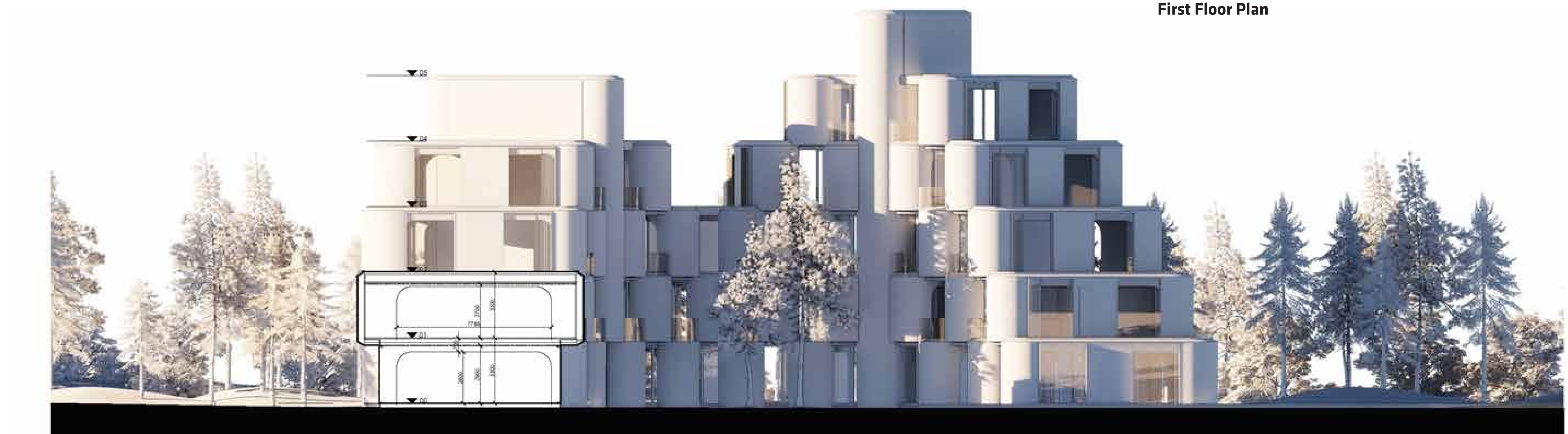
Modular System 3D Printed

Ground Floor Plan

Housing Project, Denmark

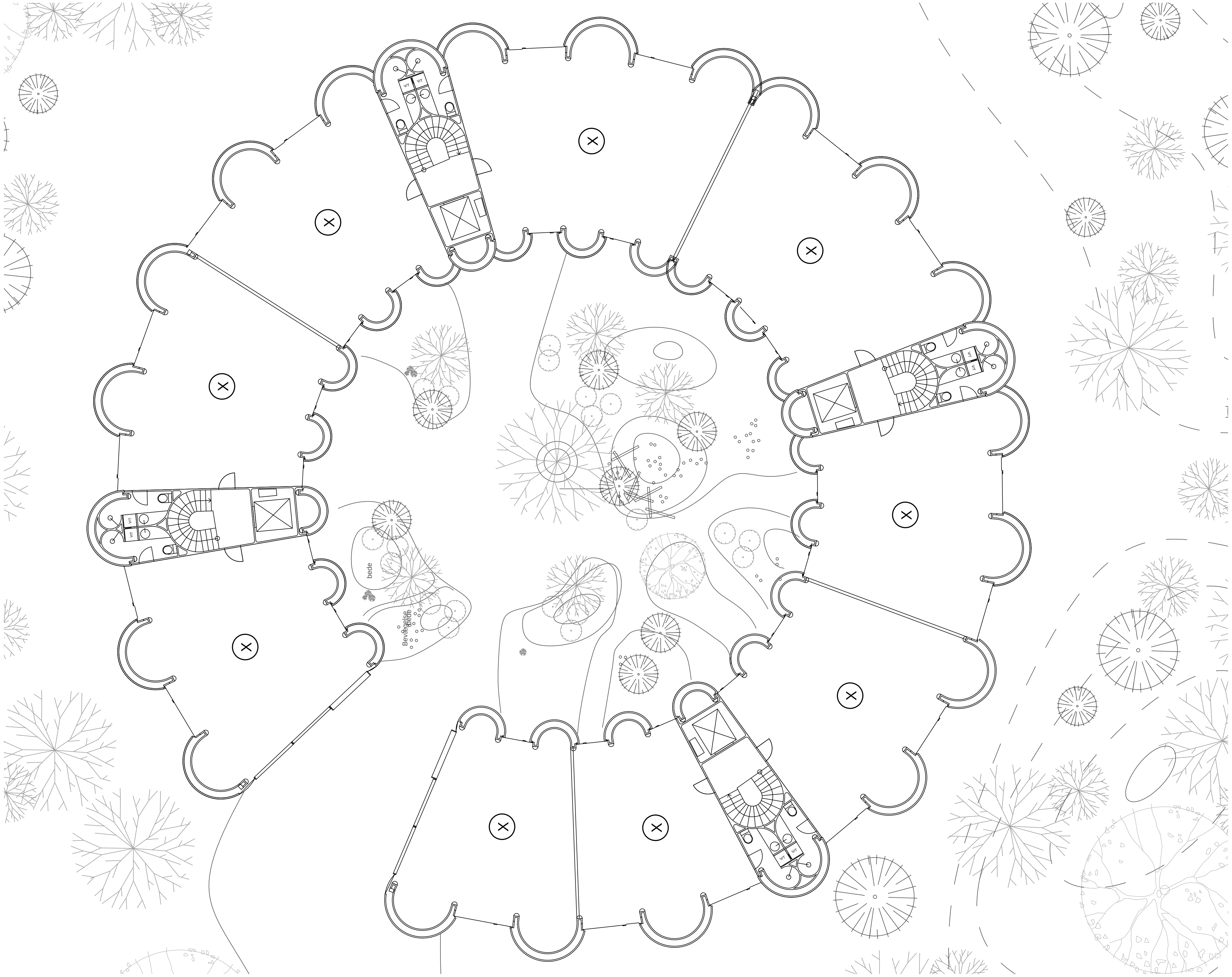


First Floor Plan



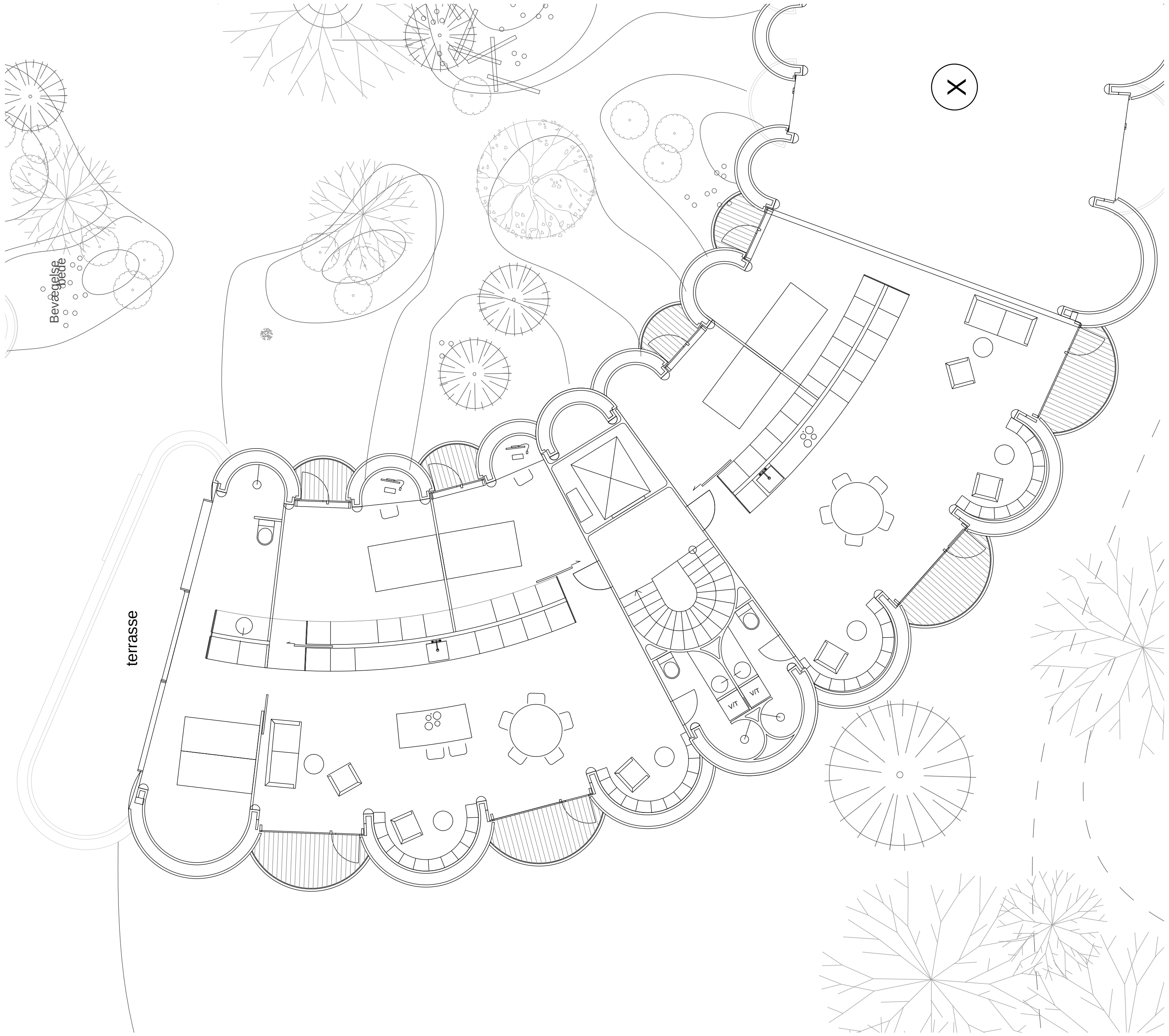
Section

Housing Project, Denmark

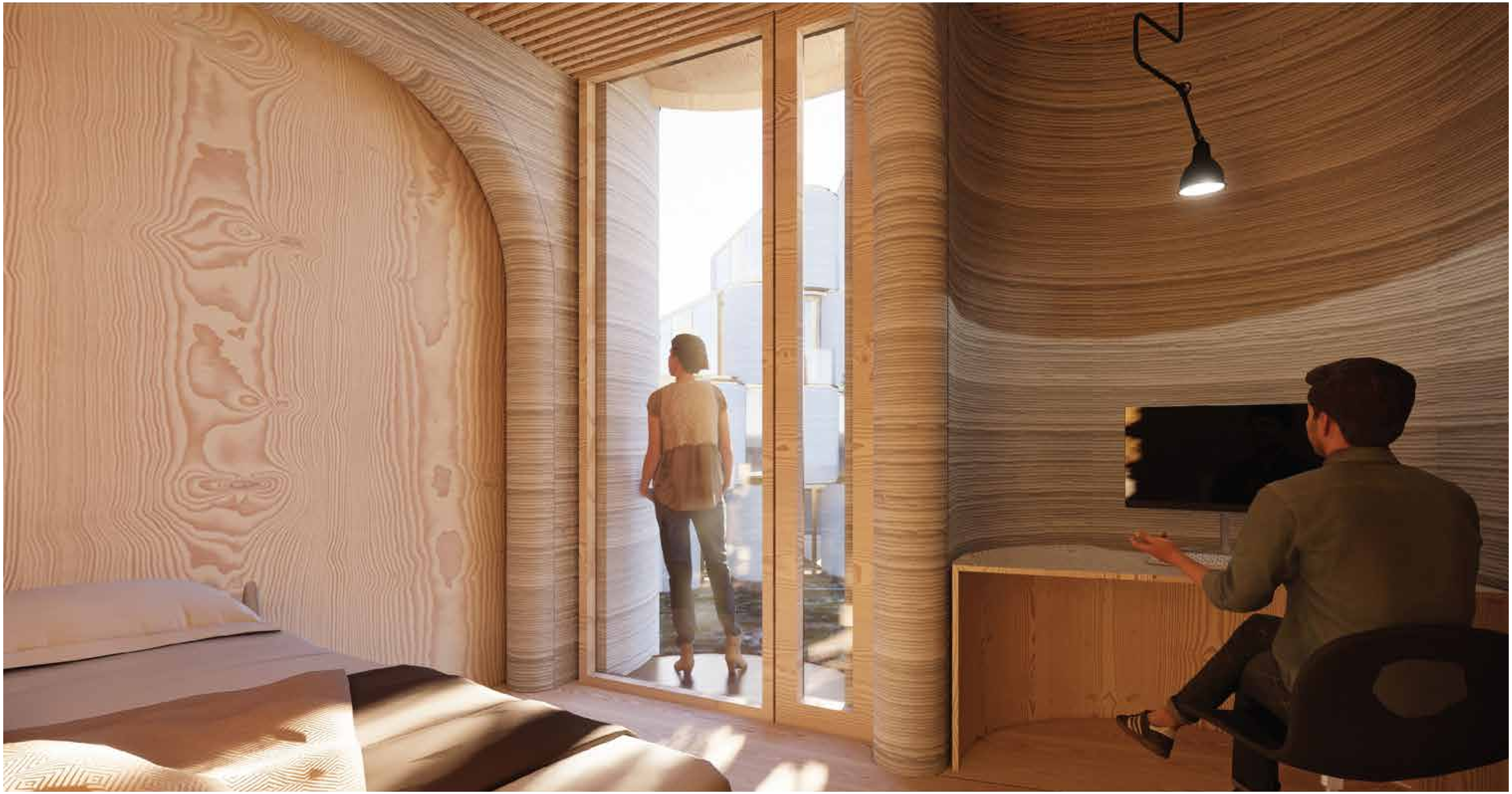


Ground Floor Plan

Housing Project, Denmark - Studies



Second Floor Plan



Housing Project, Denmark - Studies

Diagram & Plan & Axo - Explanatory Drawings

Diagram & Plan & Axo - Explanatory Drawings

Housing Project, Denmark - Studies

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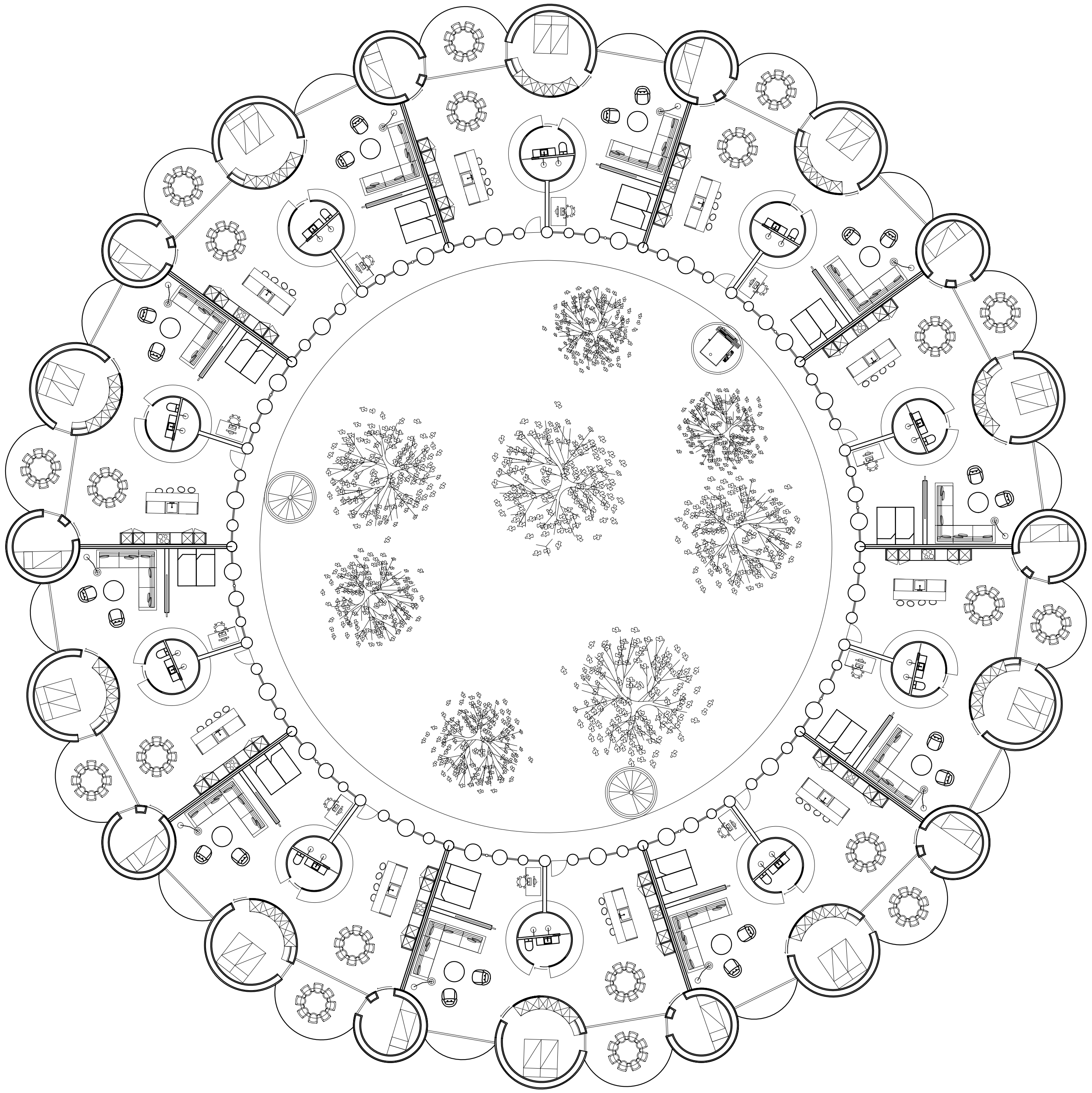
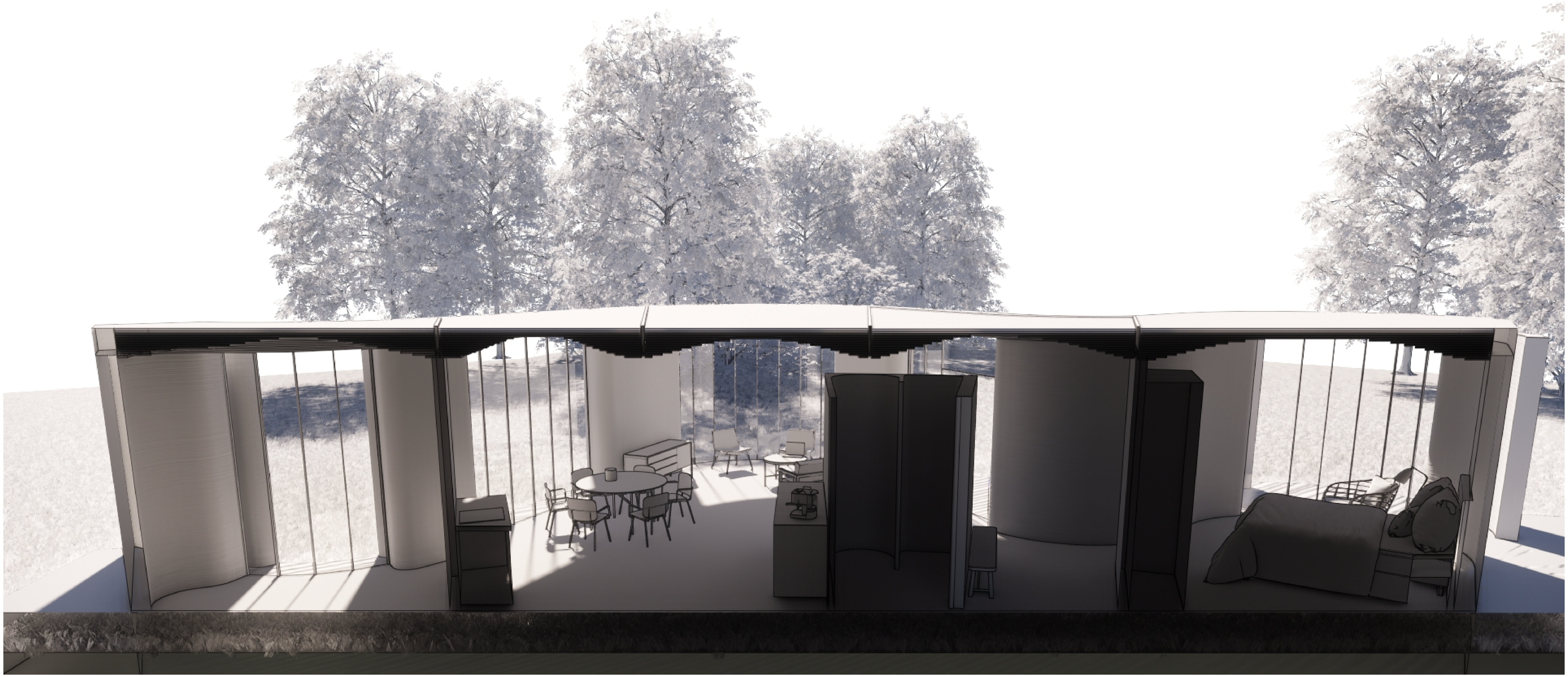
Housing Project, Denmark - Studies



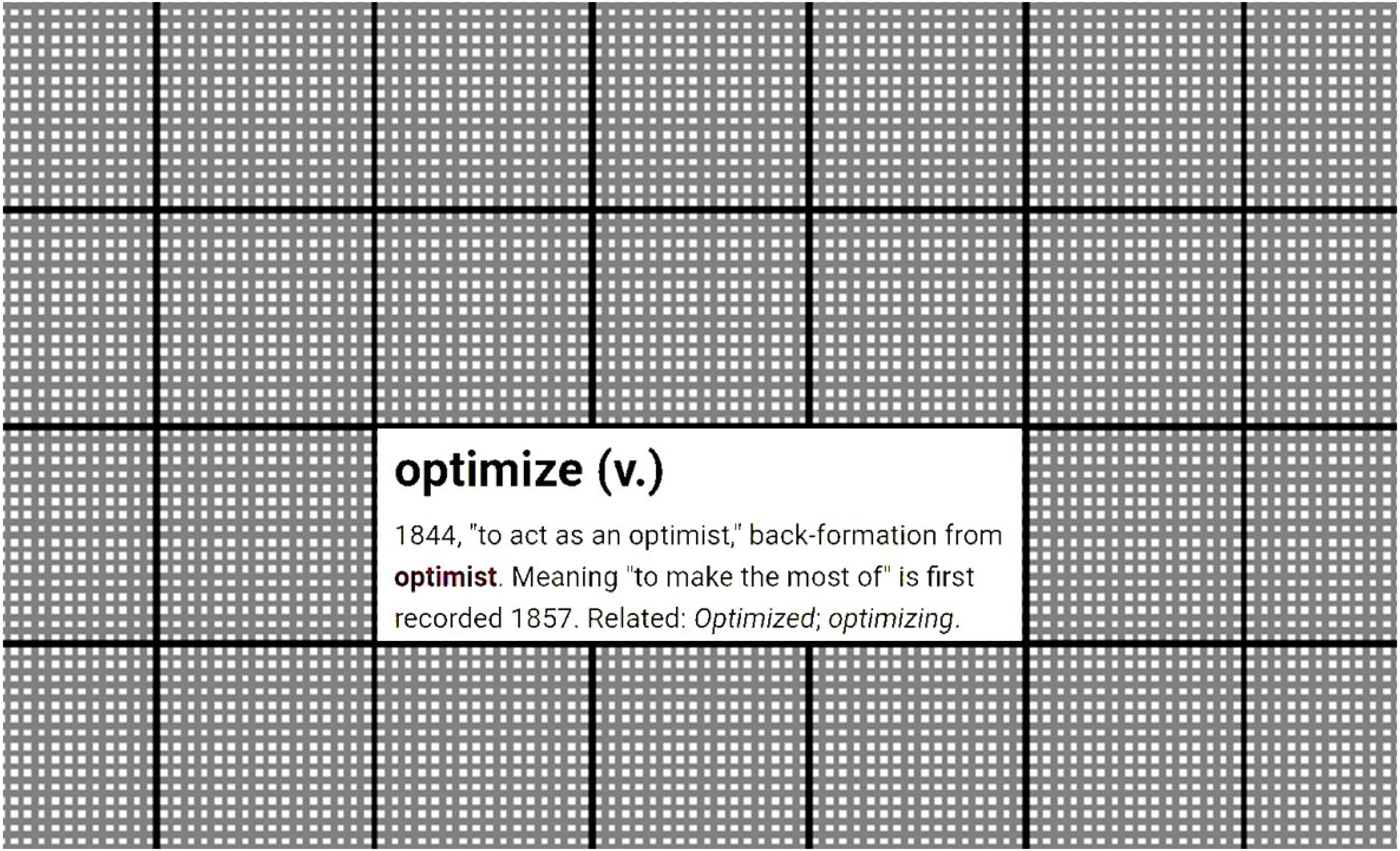
Housing Project, Denmark - Studies

Housing Project, Denmark

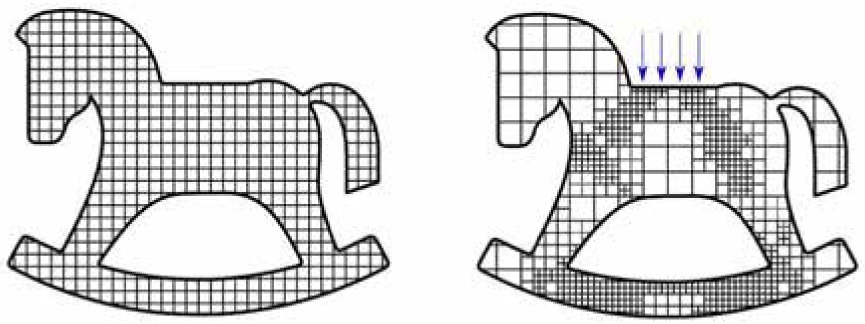
Housing Project, Denmark



OPTIMIZE DEFINITION - PROOF OF CONCEPT



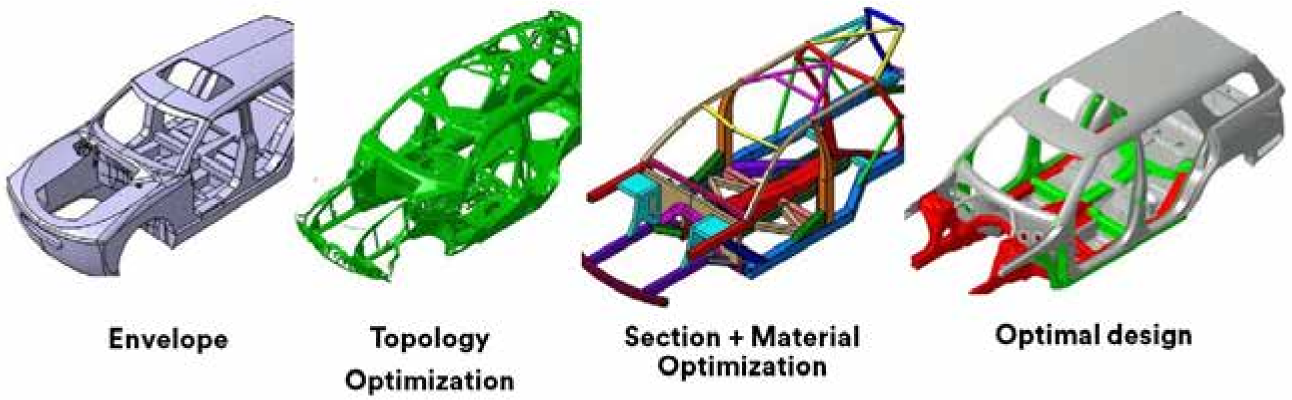
Topology optimization – any object



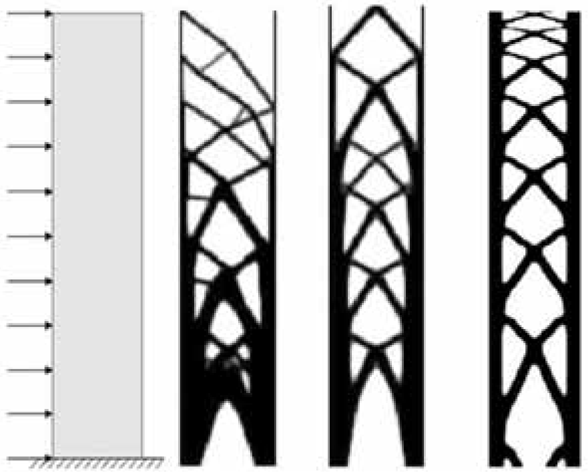
Topology optimization – small scale

Present day: Topology optimization and/or 3d printing

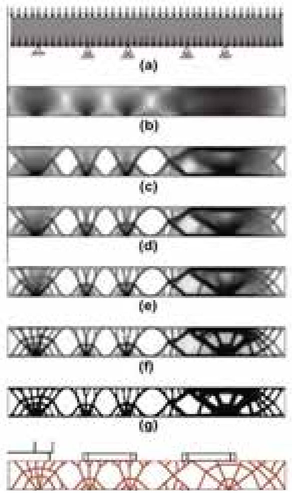
The car industry



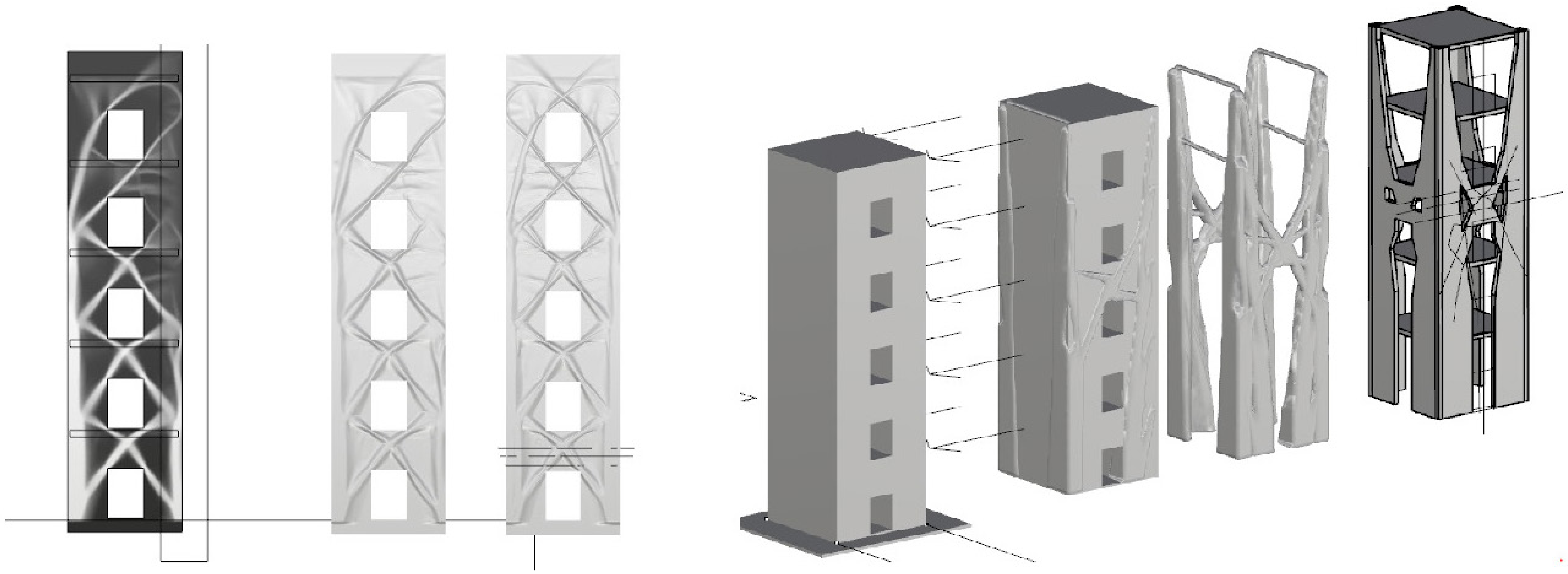
Topology optimization



Topology optimization



Typology Optimization / Structural Elements



Typology Optimization of cores

CORE AND COLUMN STUDIES 01.

CORE AND COLUMN STUDIES 02.

CORE AND COLUMN STUDIES 03.

CORE AND COLUMN STUDIES 04.

Typology Optimization / Structural Elements

CORE AND COLUMN STUDIES

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Typology Optimization / Structural Elements

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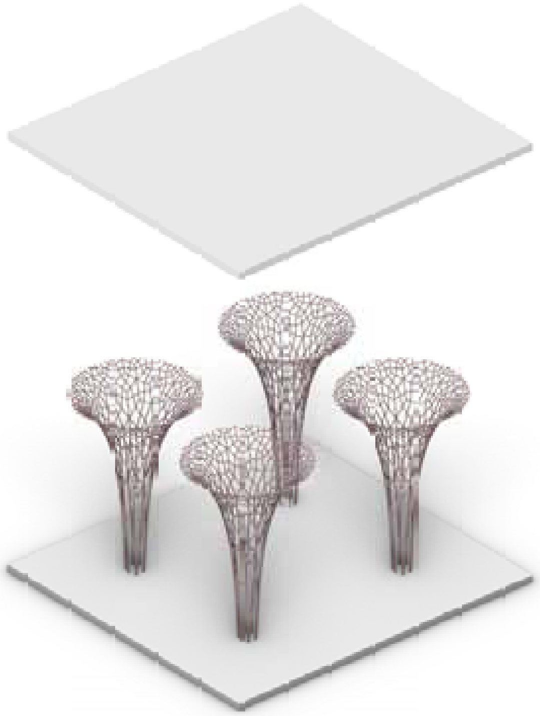
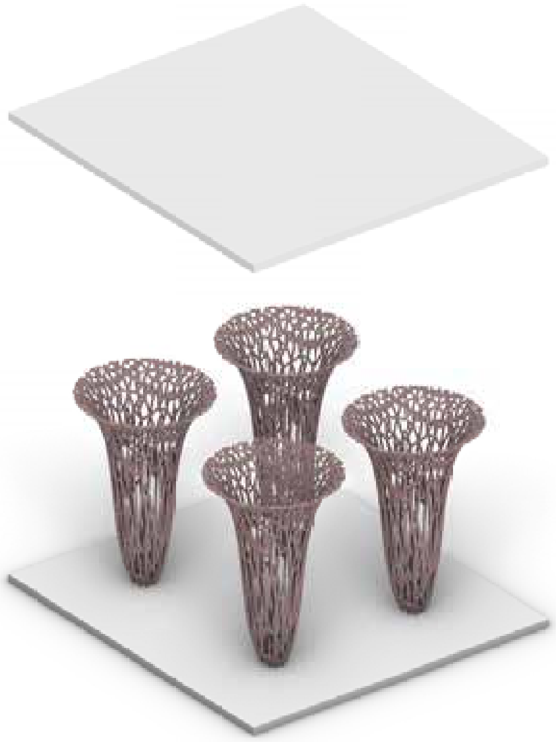
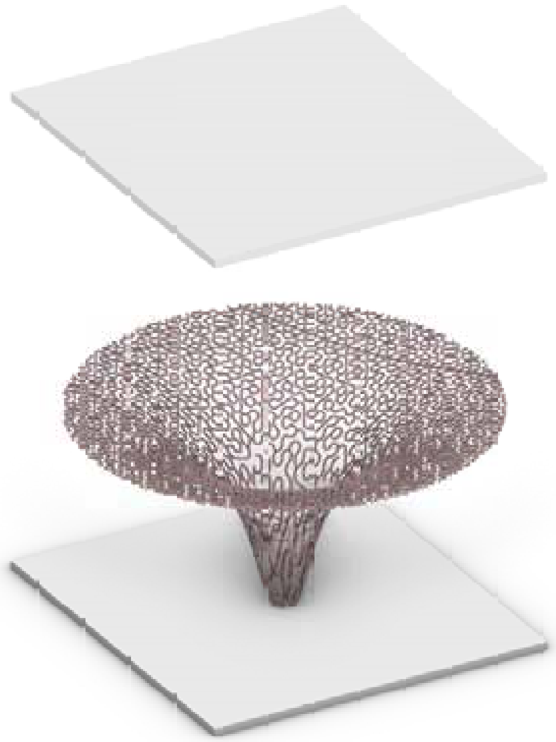
Typology Optimization / Structural Elements



20 thick elements 3D printed with extra fine nozzle optimized to save material



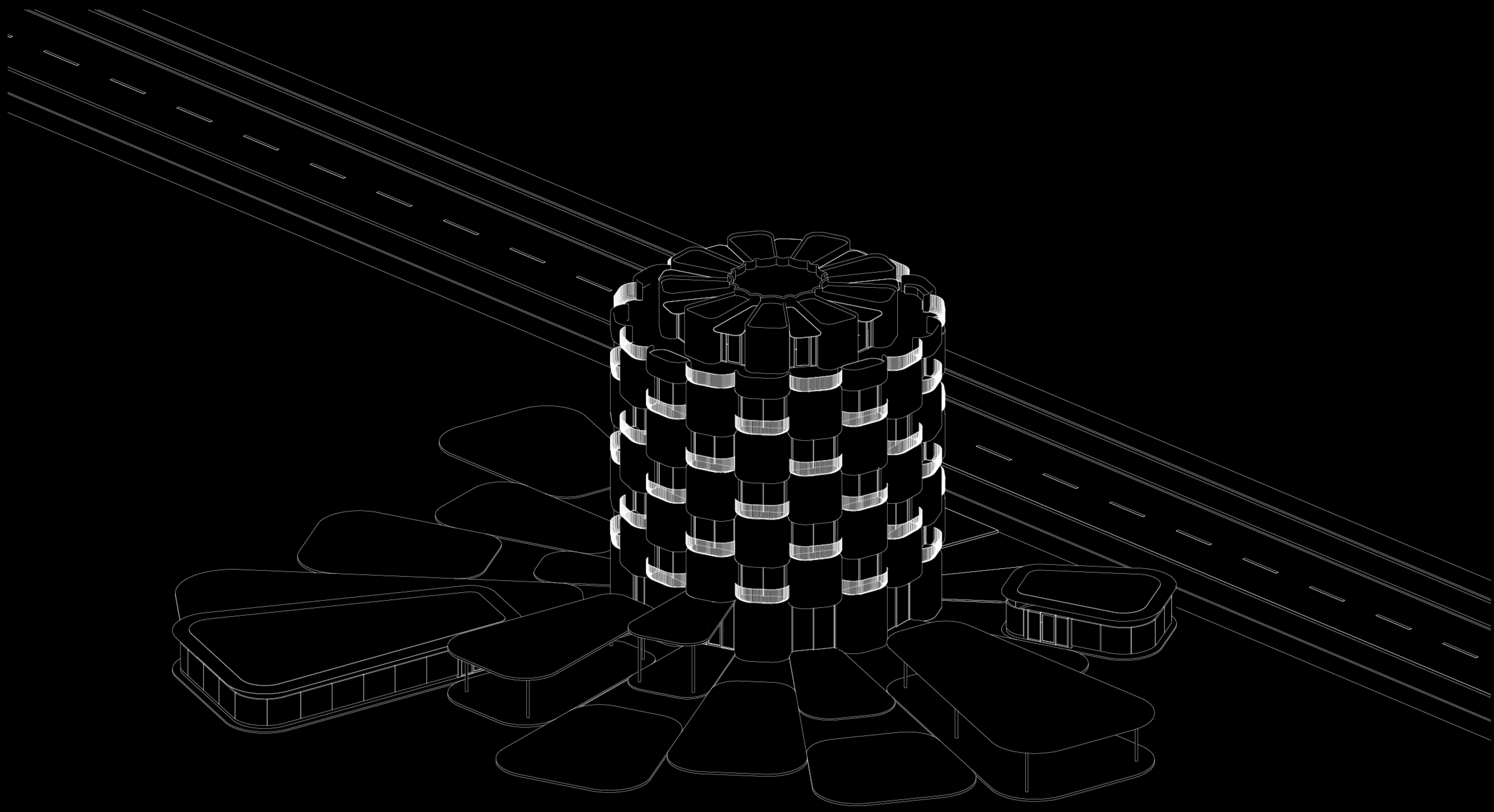
40 mil thick elements 3D printed with fine nozzle Optimized to save material



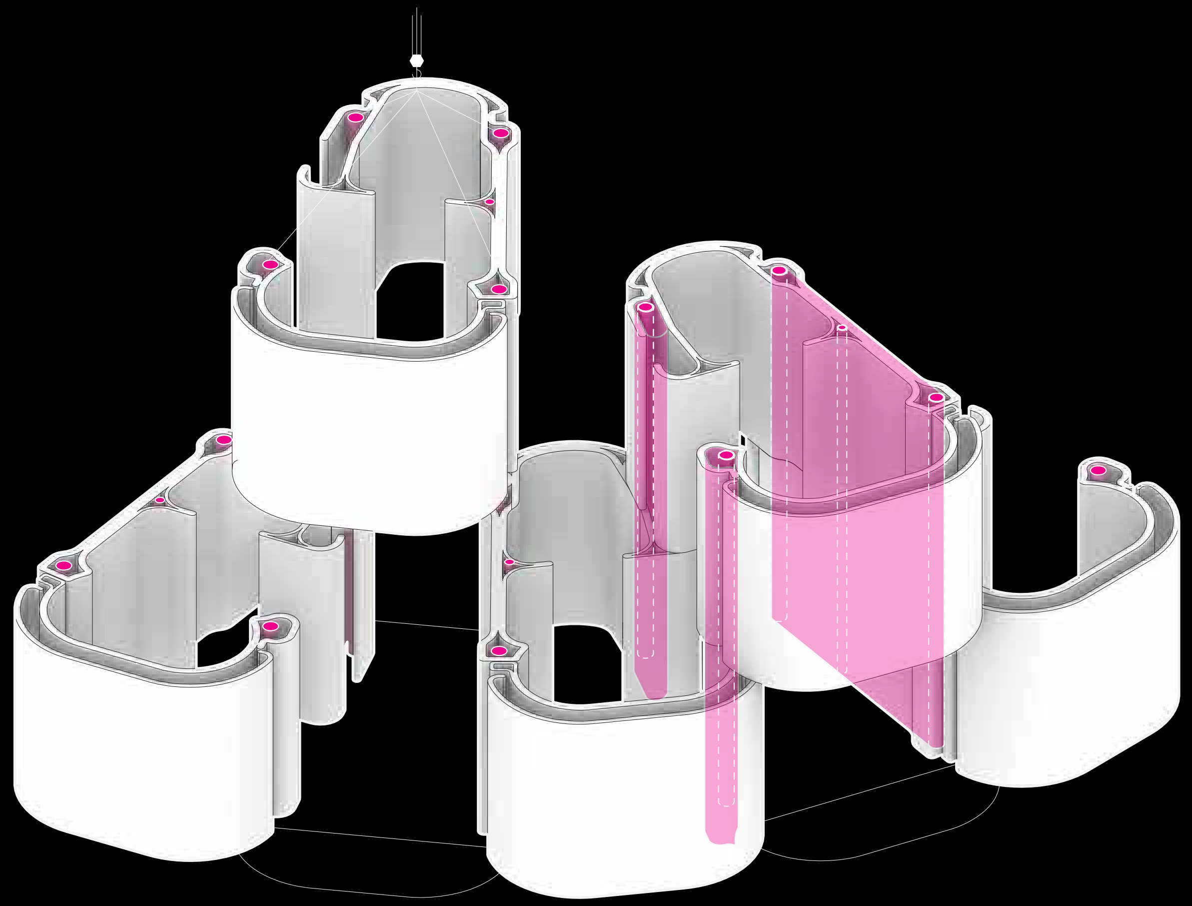
One supportive roof-column element Optimized to save material

Typology Optimization / Structural Elements

BIG

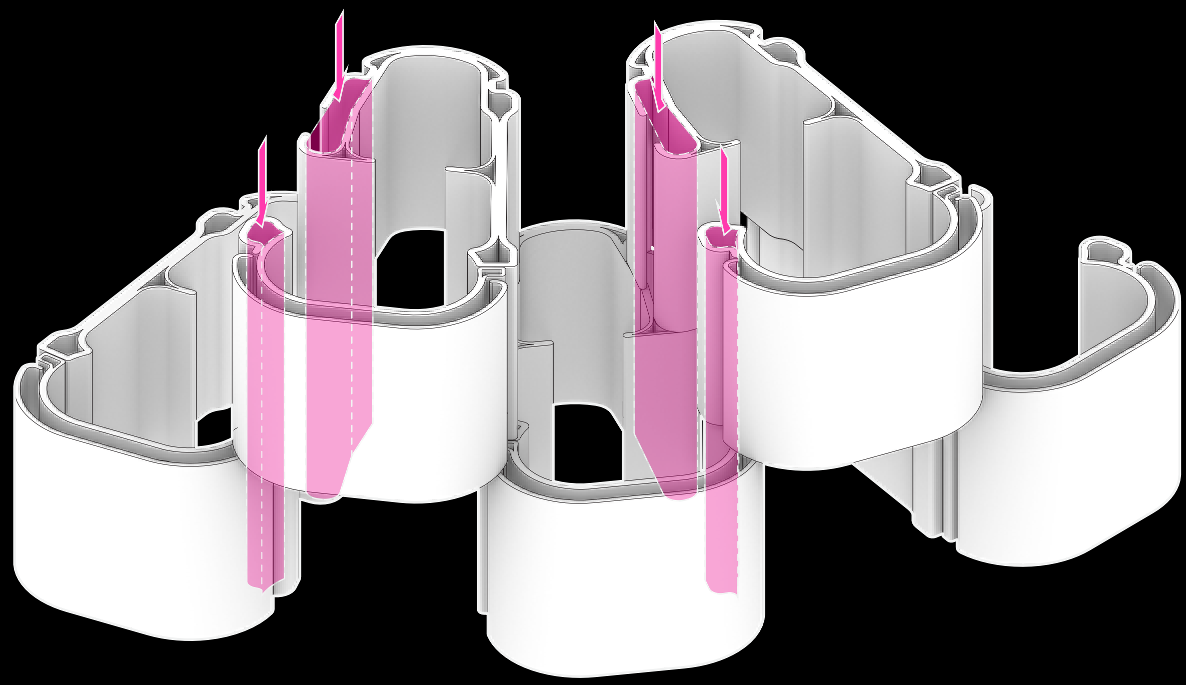


BIG - PINEAPPLE



CONTINUOUS STRUCTURE

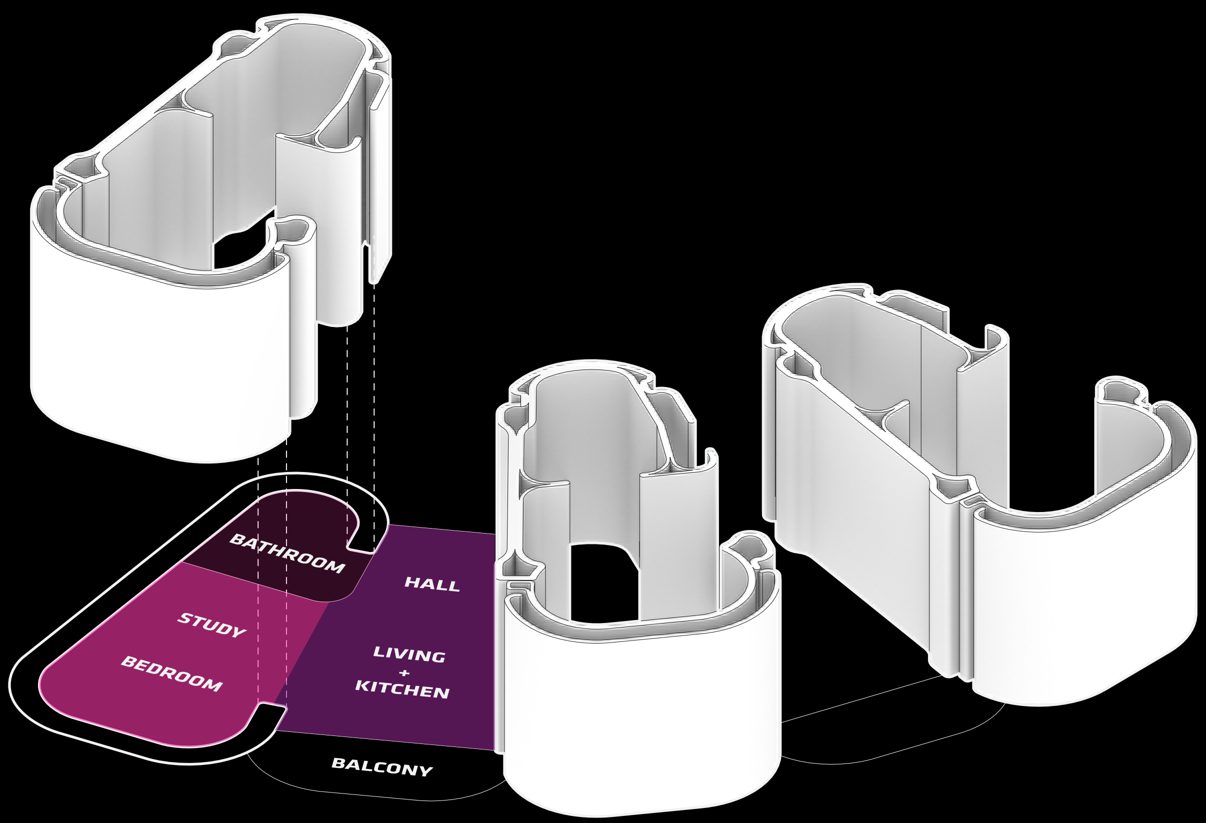
The Modular Elements Allows a Structure Easy To Construct and Deconstruct Which Creates a Reusable Structure.



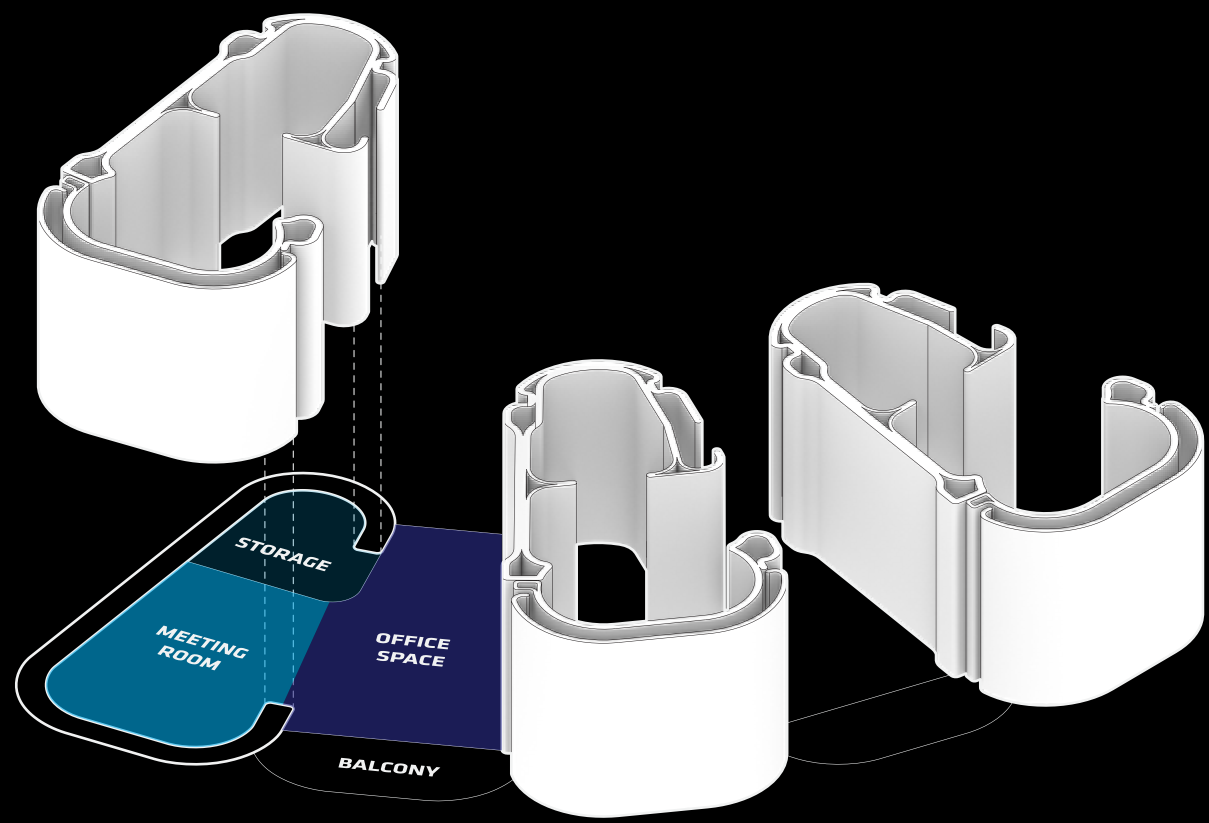
CONTINUOUS SHAFTS

The Modular Elements Alows To Create Continuous Shafts and Reduces or omits extra MEP inlaid Shafts

INSTALLATION AND STRUCTURE



HOUSING



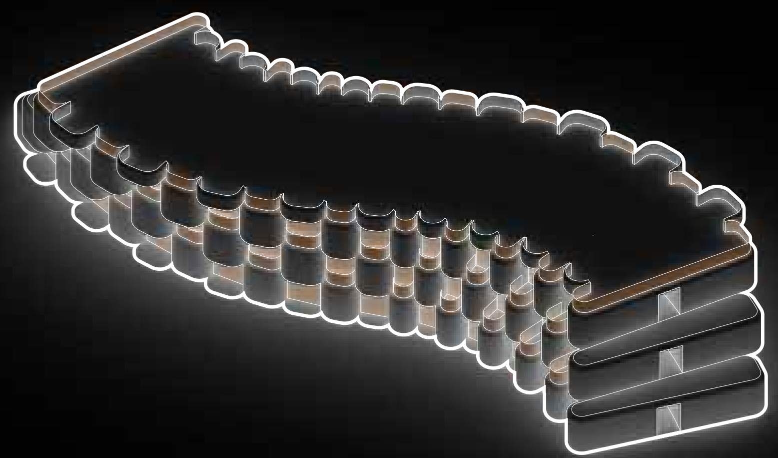
OFFICE

FLEXIBLE DESIGN

HOUSING

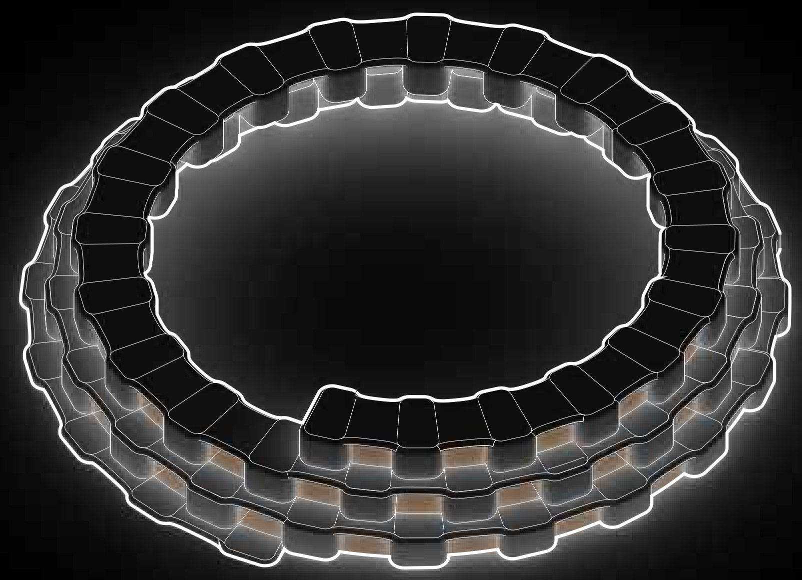
OFFICE

FLEXIBLE DESIGN



LINEAR

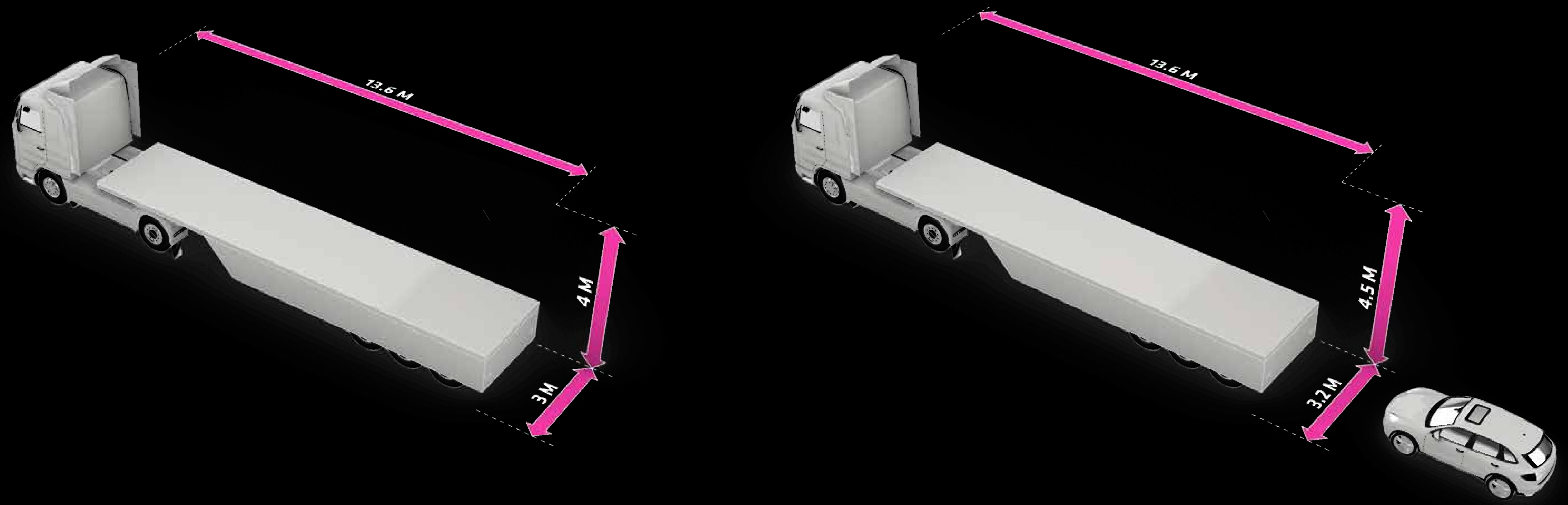
POINT



COURTYARD

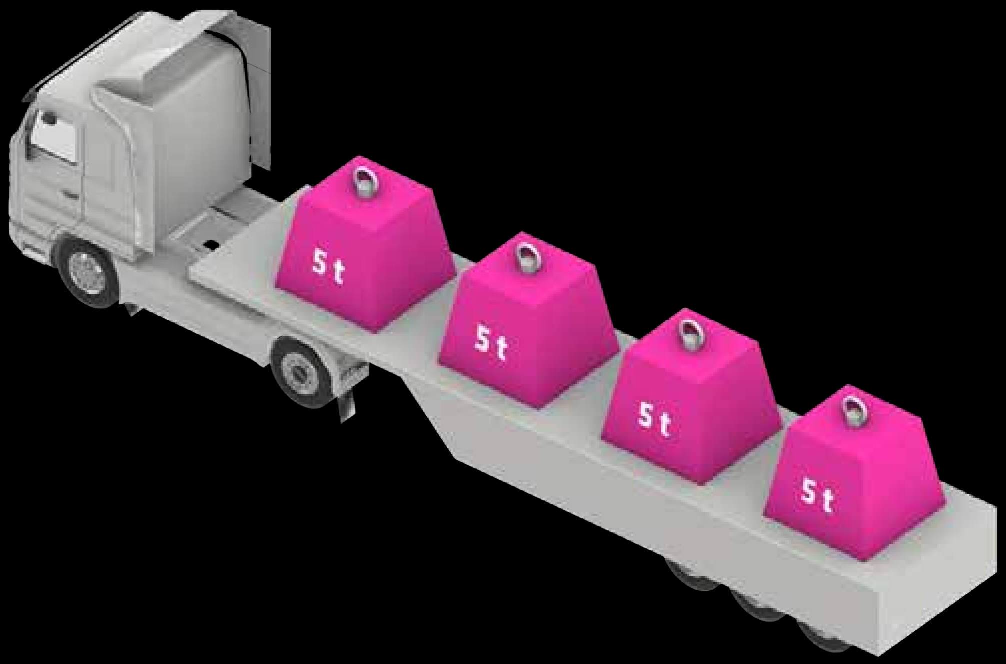
The Modularity of The Units Allows Diffrent Layouts and Flexibility On Site

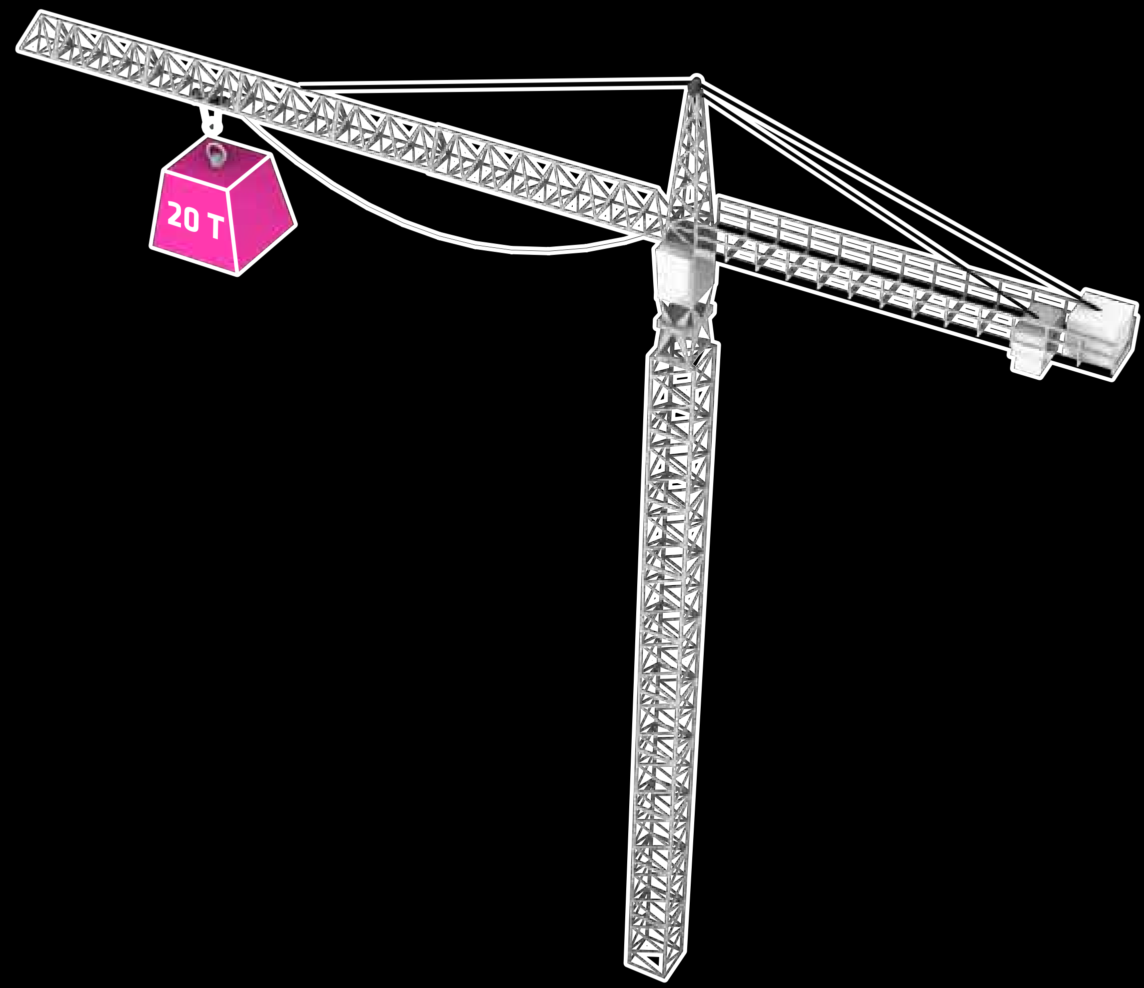
FLEXIBLE DESIGN



When it Comes to Transportation There is Some Off Site Constraints Like The Maximum Dimensions That we Can Build to Able to Transport is Important to Take in Considiration When Designing the Units to Reach the **Maximum Efficiency**

OFF SITE CONSTRAINTS



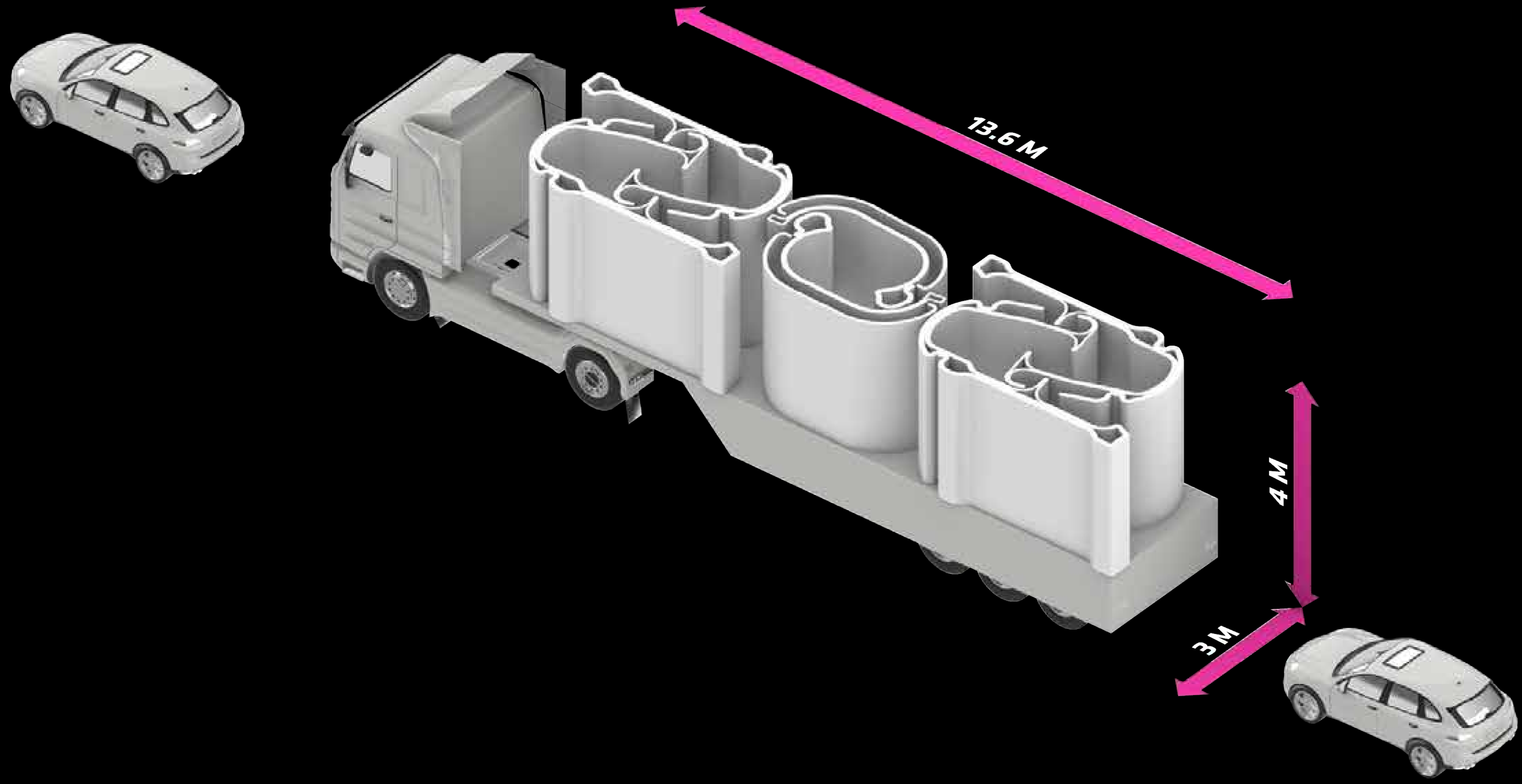


The Weight Of Each Unit is Also an Important Parameter When It Comes to Efficiency. Our Goal is to Reduce the Amount of Lifting and Transportation as Much as Possible to be More **Time and Cost Efficient** for Transporting the Units.

OFF SITE CONSTRAINTS

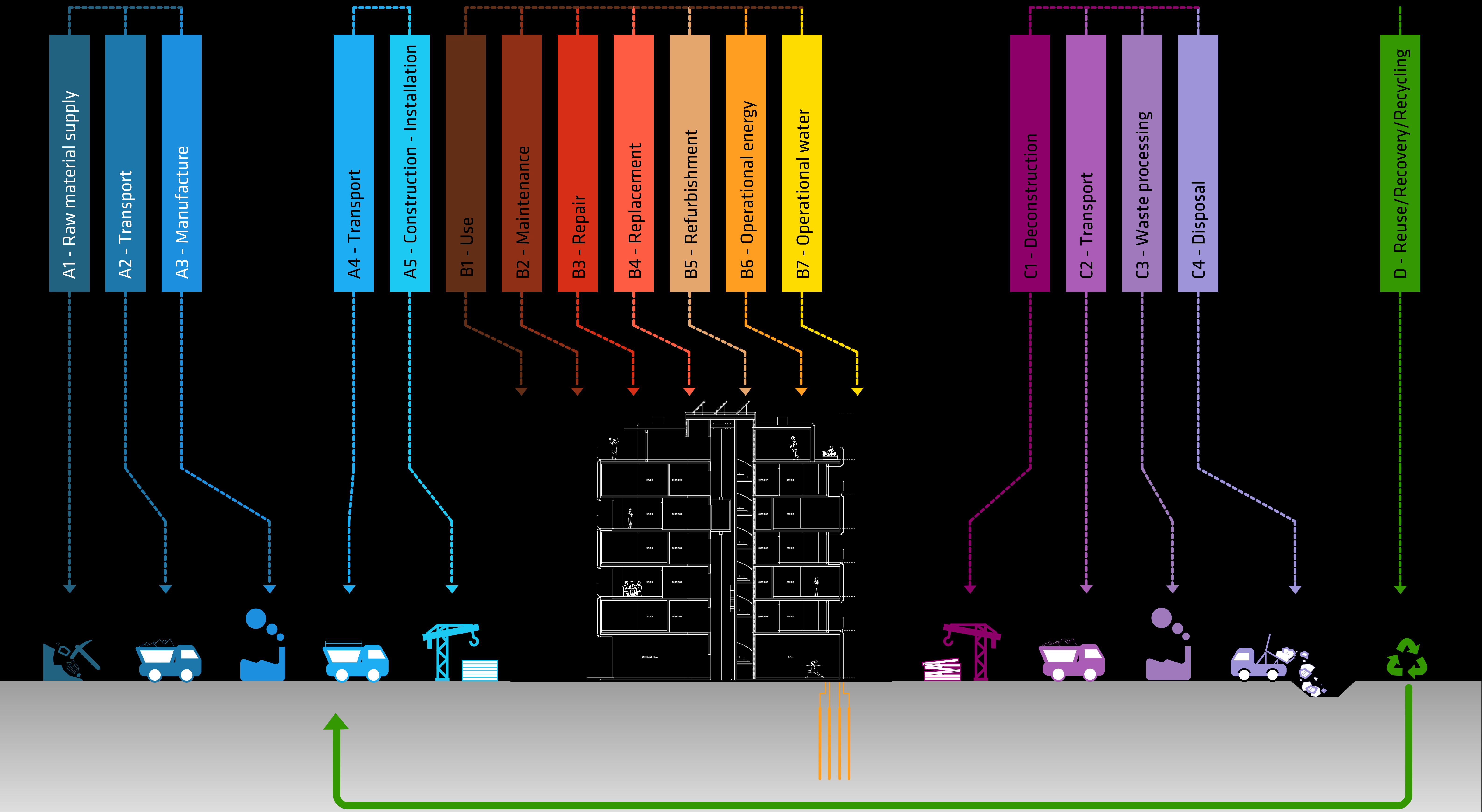
Each Unit Is Divided Into Two Pieces To Make The Transportation More Efficient

OFF SITE CONSTRAINTS



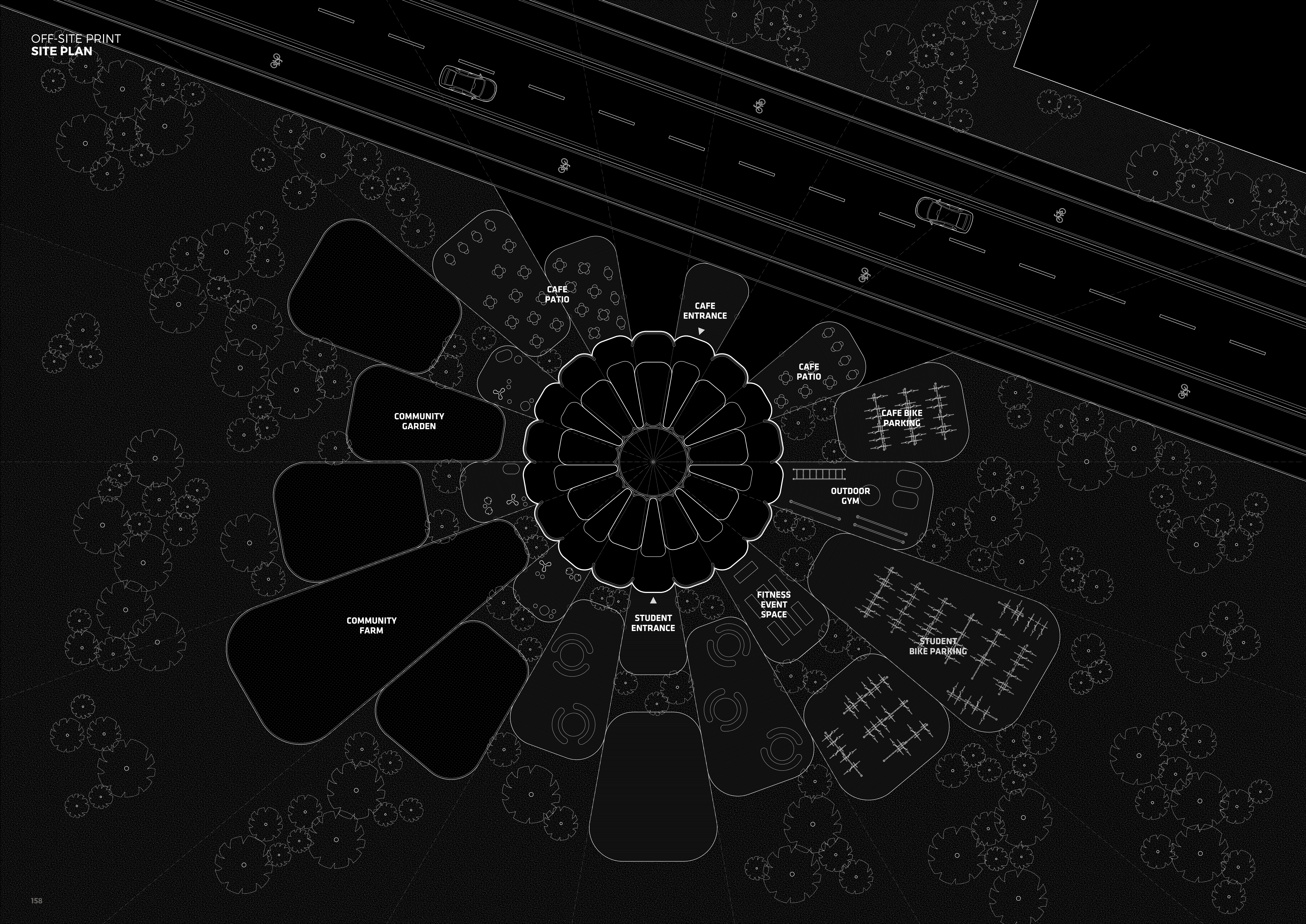
Taking in Consider The Constrains We are able to Transport **4 Units** at the Same Time Which Allows Us to Reduce the Time and Cost for the Transportation and Significant **Carbon Savings** In Transportation.

OFF SITE CONSTRAINTS



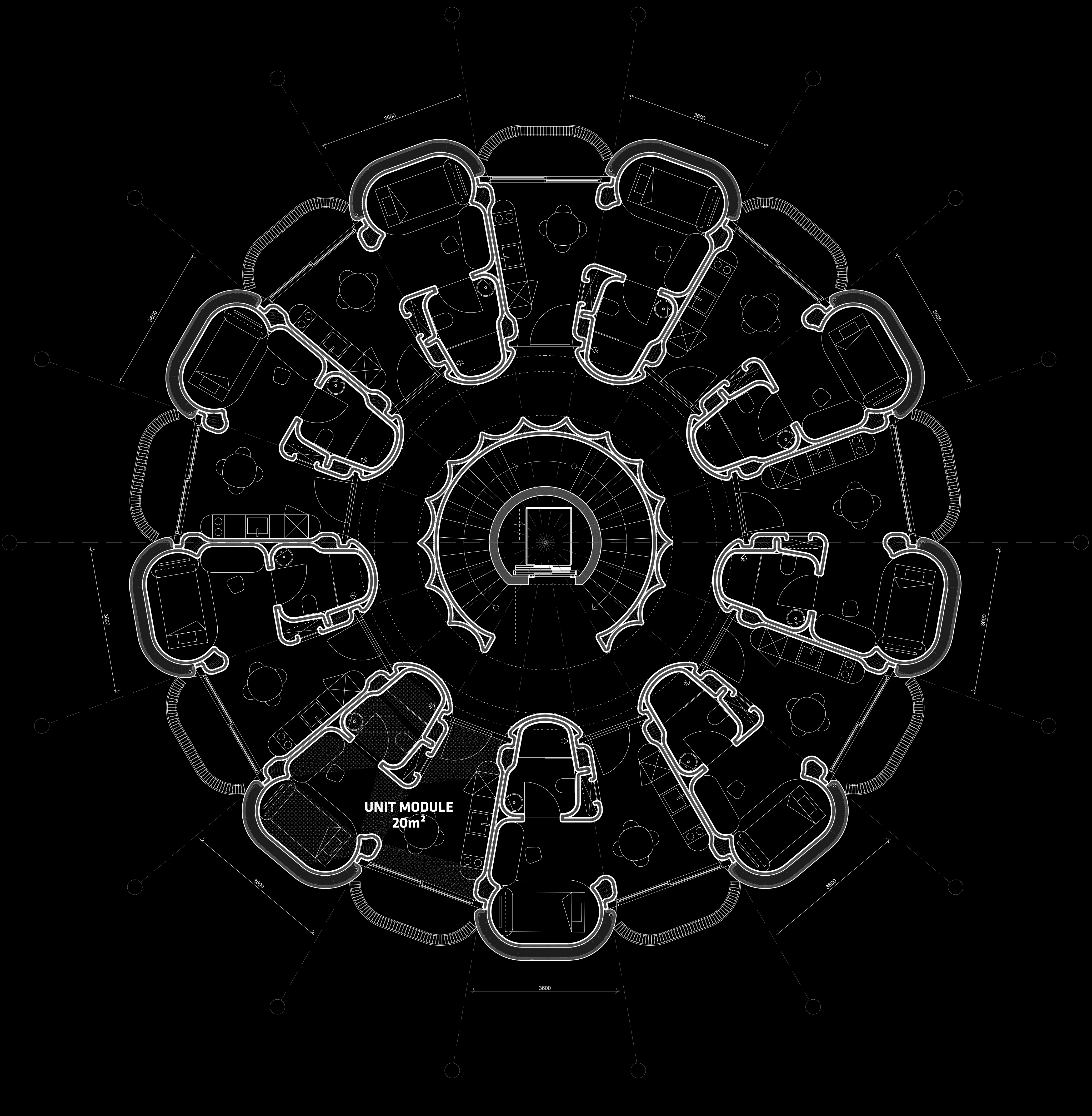
LIFECYCLE ANALYSIS STAGES

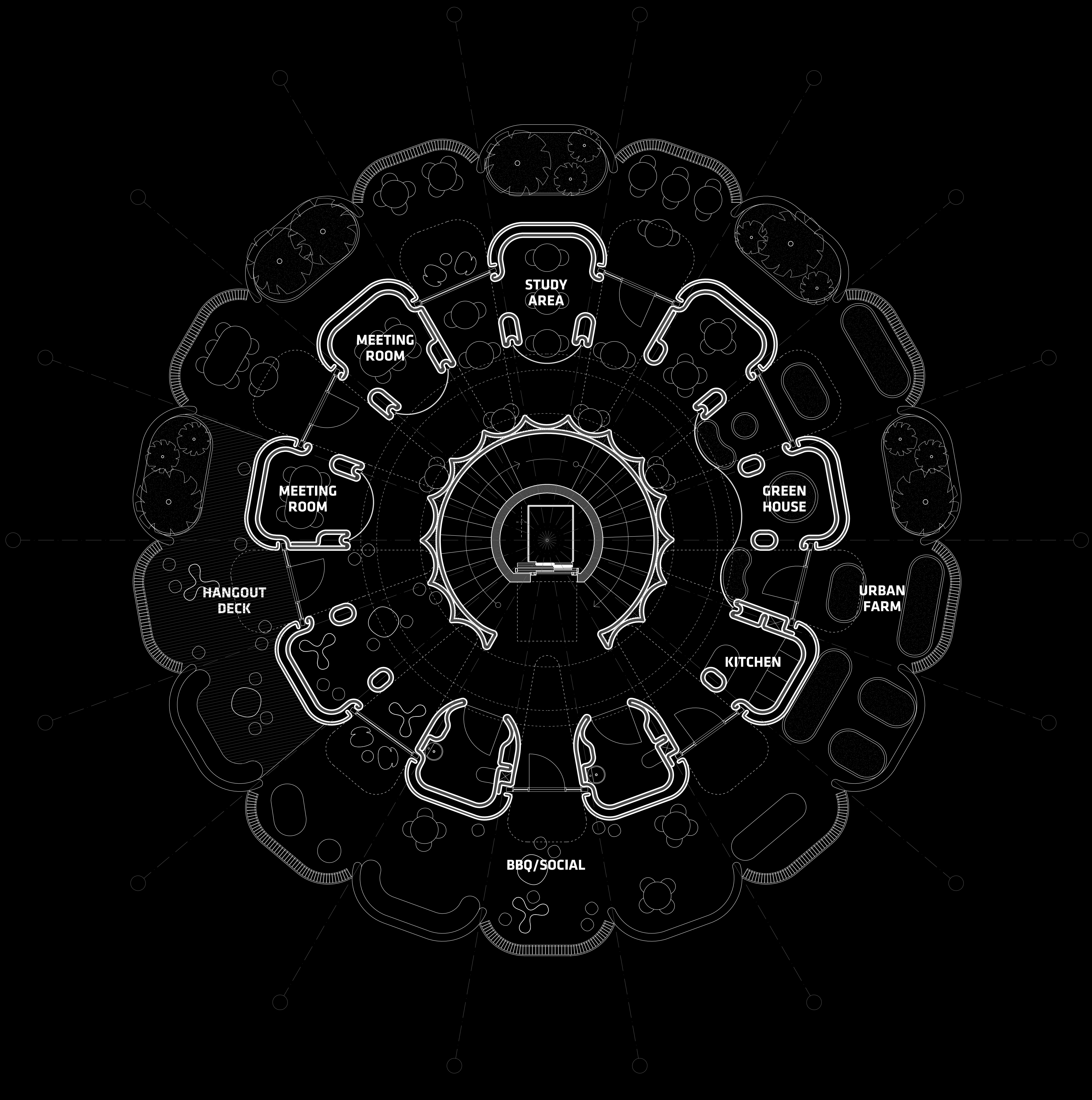
OFF-SITE PRINT
SITE PLAN

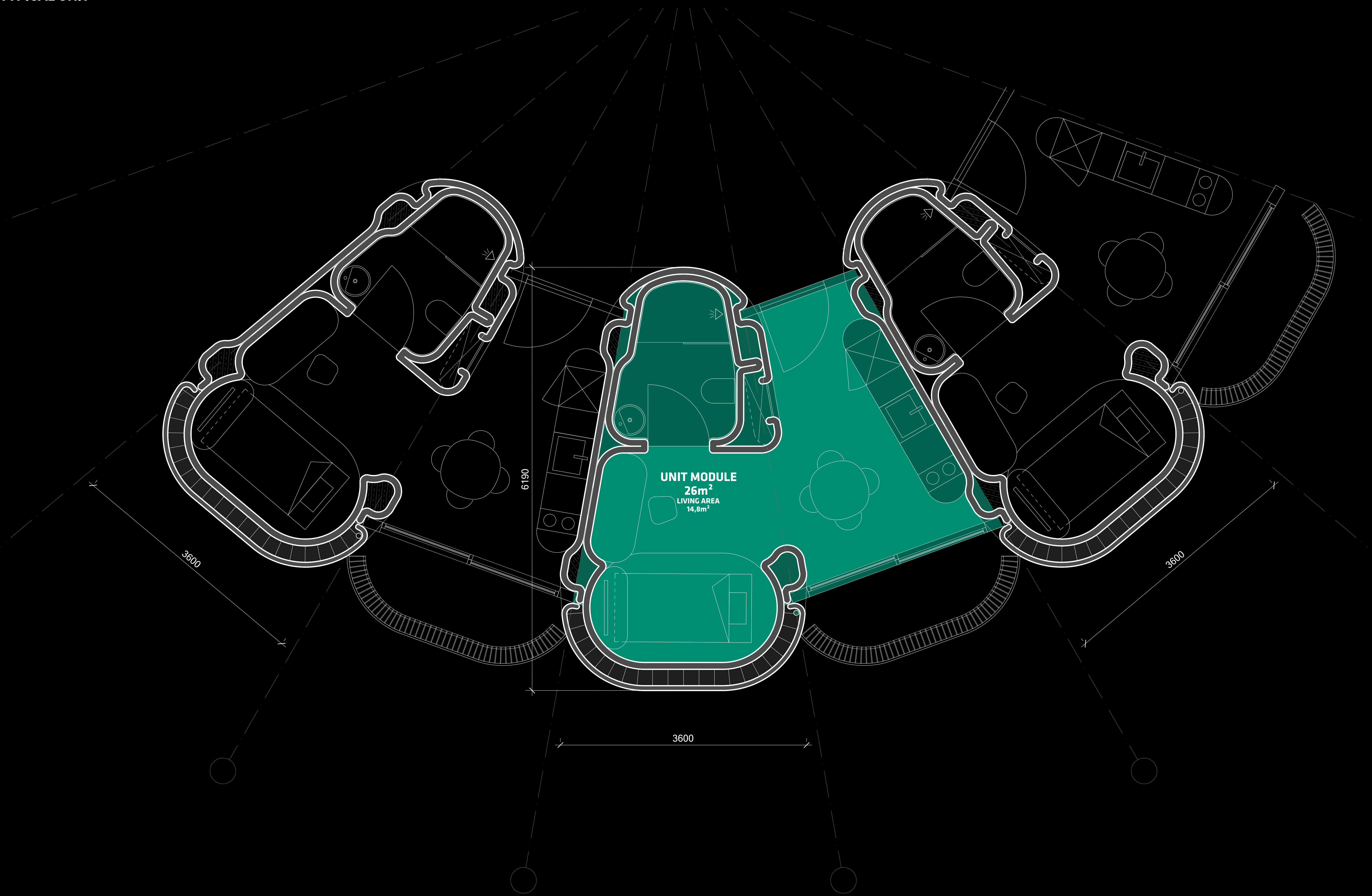


OFF-SITE PRINT
GROUND FLOOR PLAN

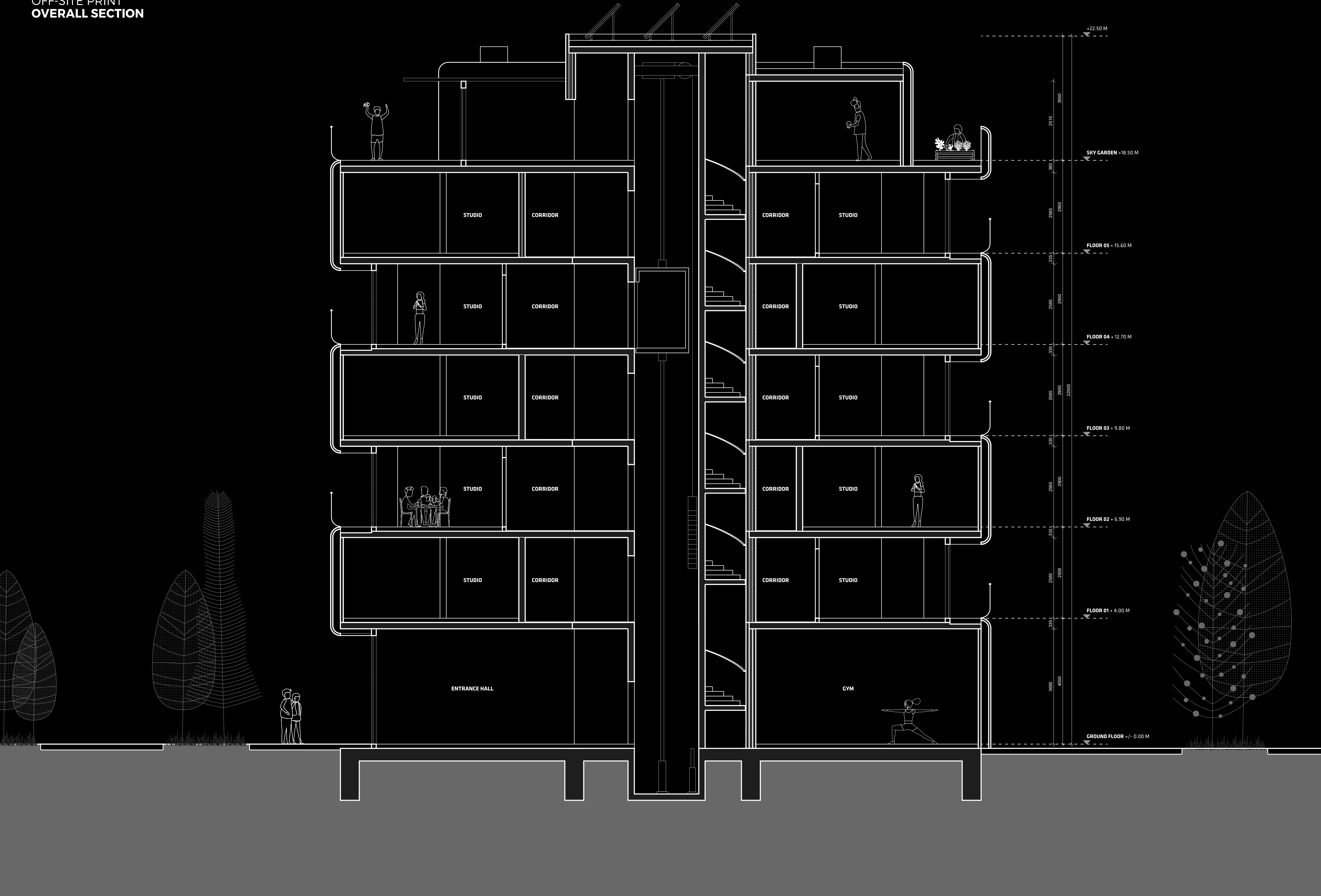
TYPICAL FLOOR PLAN

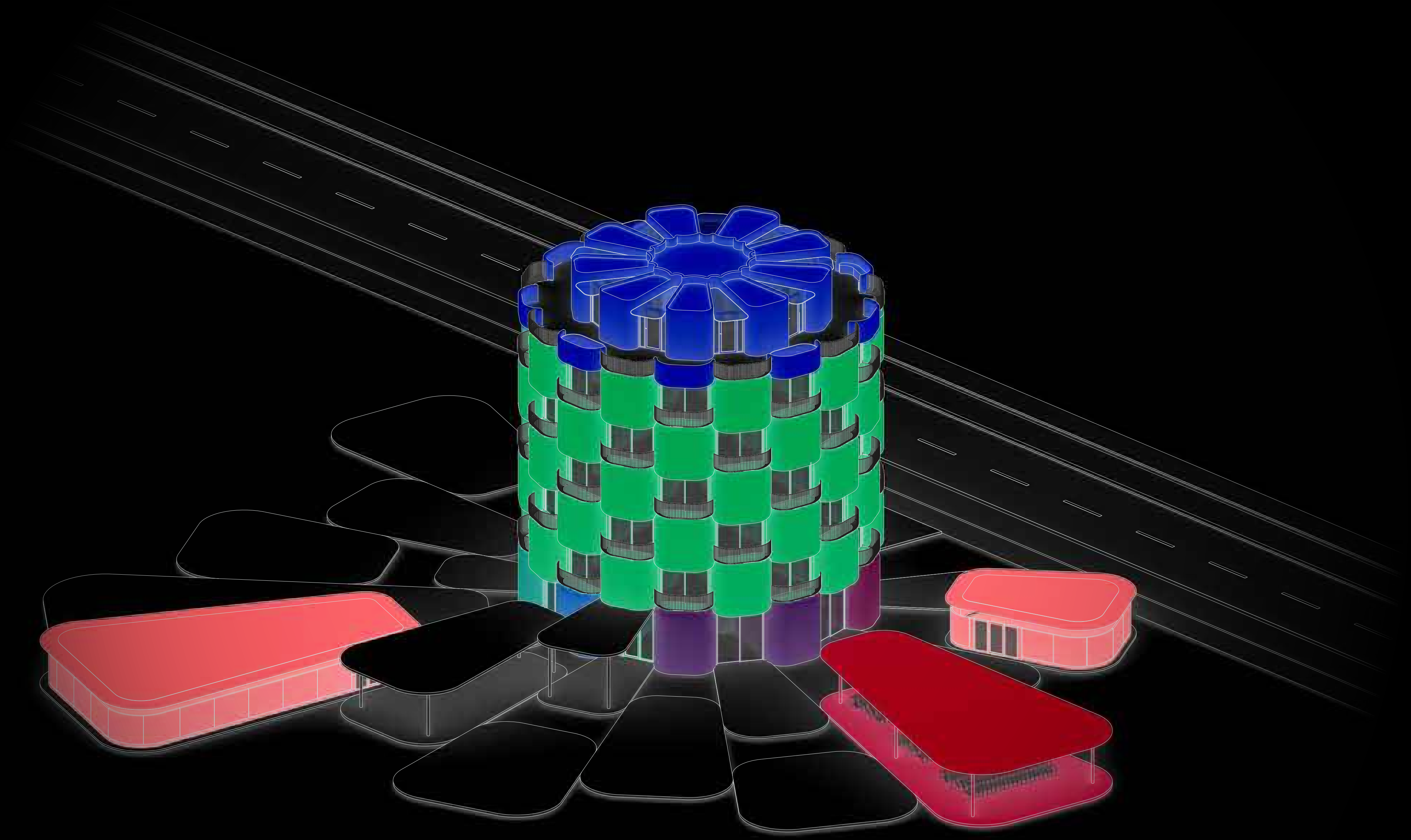



STUDY AREA
MEETING ROOM
MEETING ROOM
GREEN HOUSE
HANGOUT DECK
URBAN FARM
KITCHEN
BBQ/SOCIAL

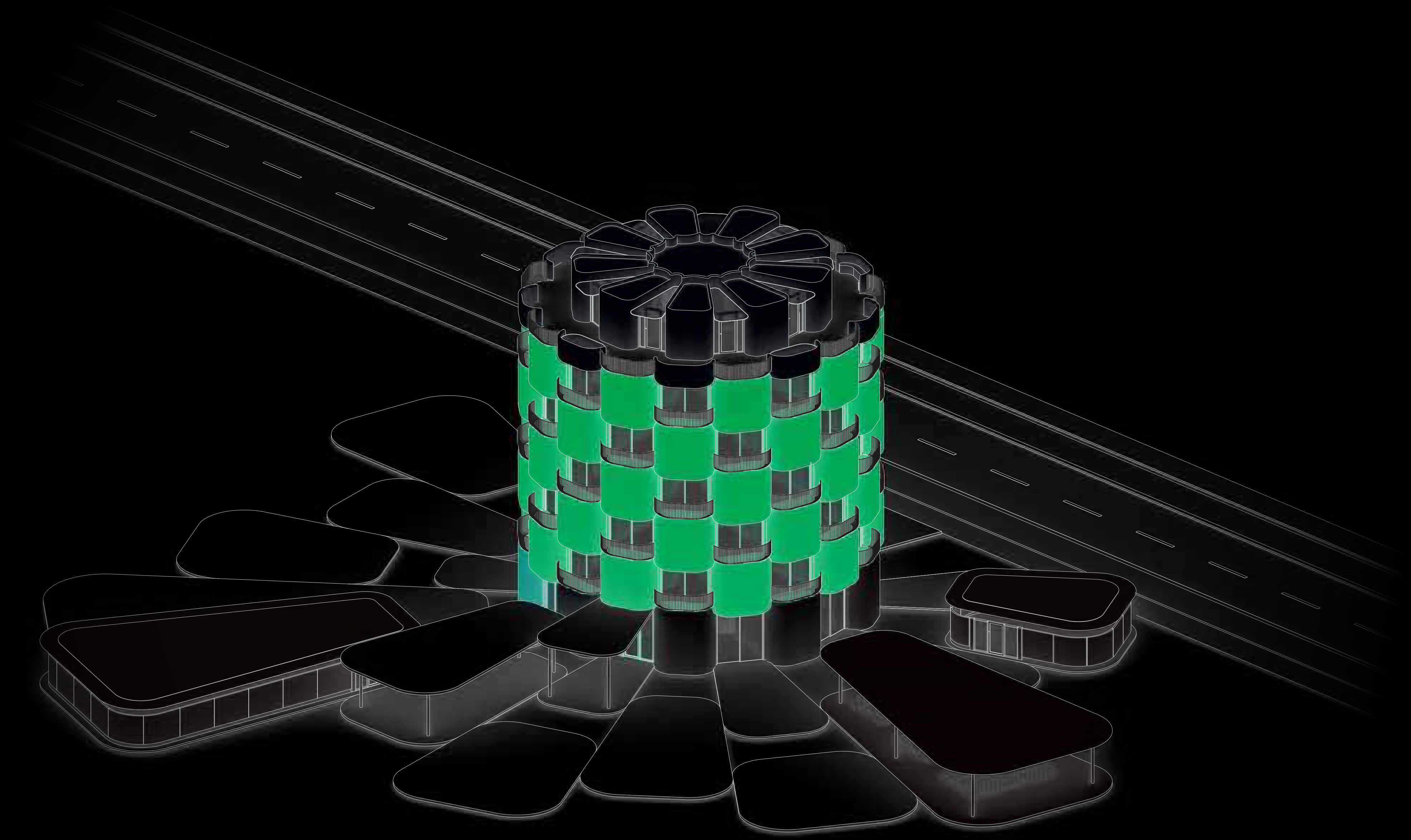

UNIT MODULE
26m²
LIVING AREA
14,8m²
6190
3600
3600
3600

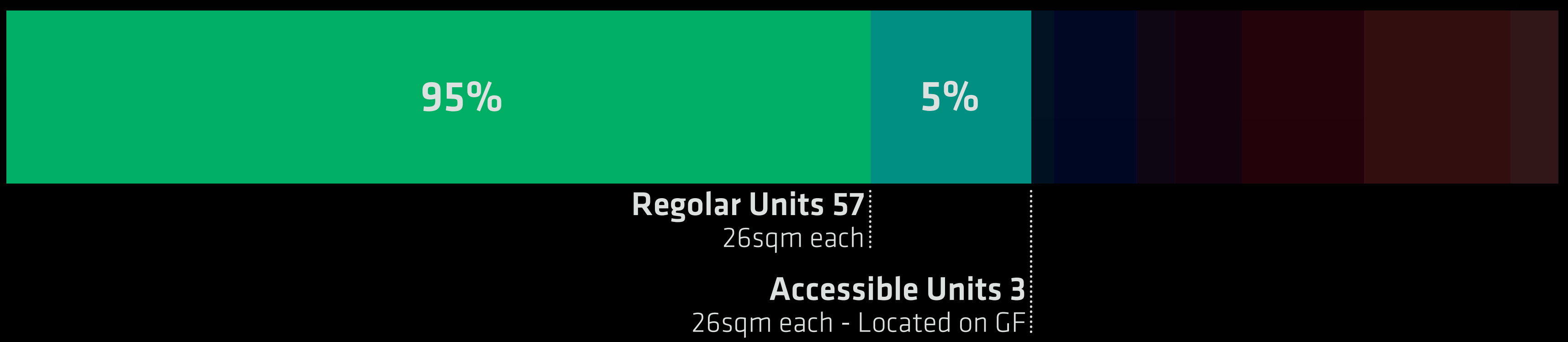
OFF-SITE PRINT
OVERALL SECTION

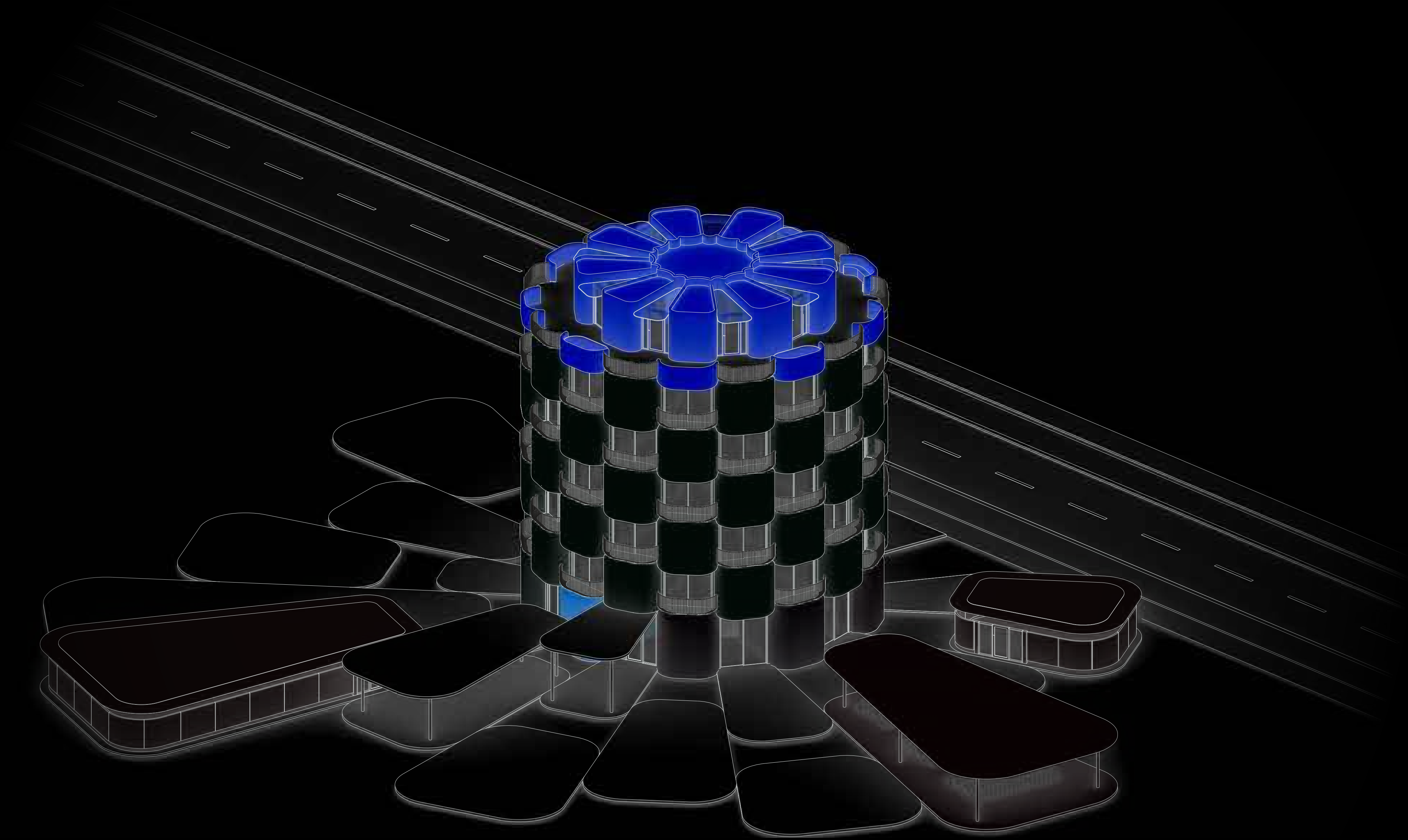


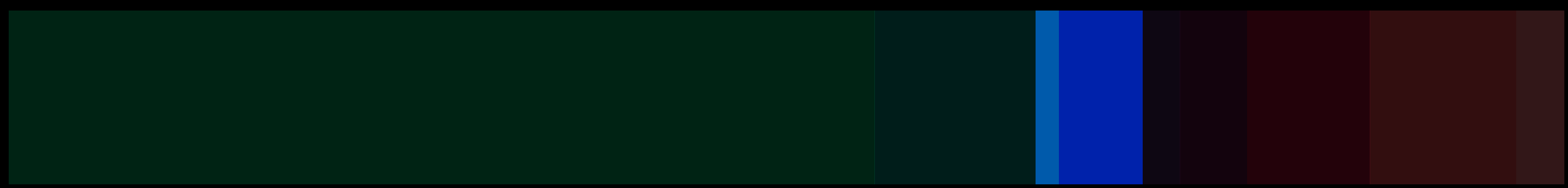



LIVING
COMMON
COMMERCIAL
SUPPORT

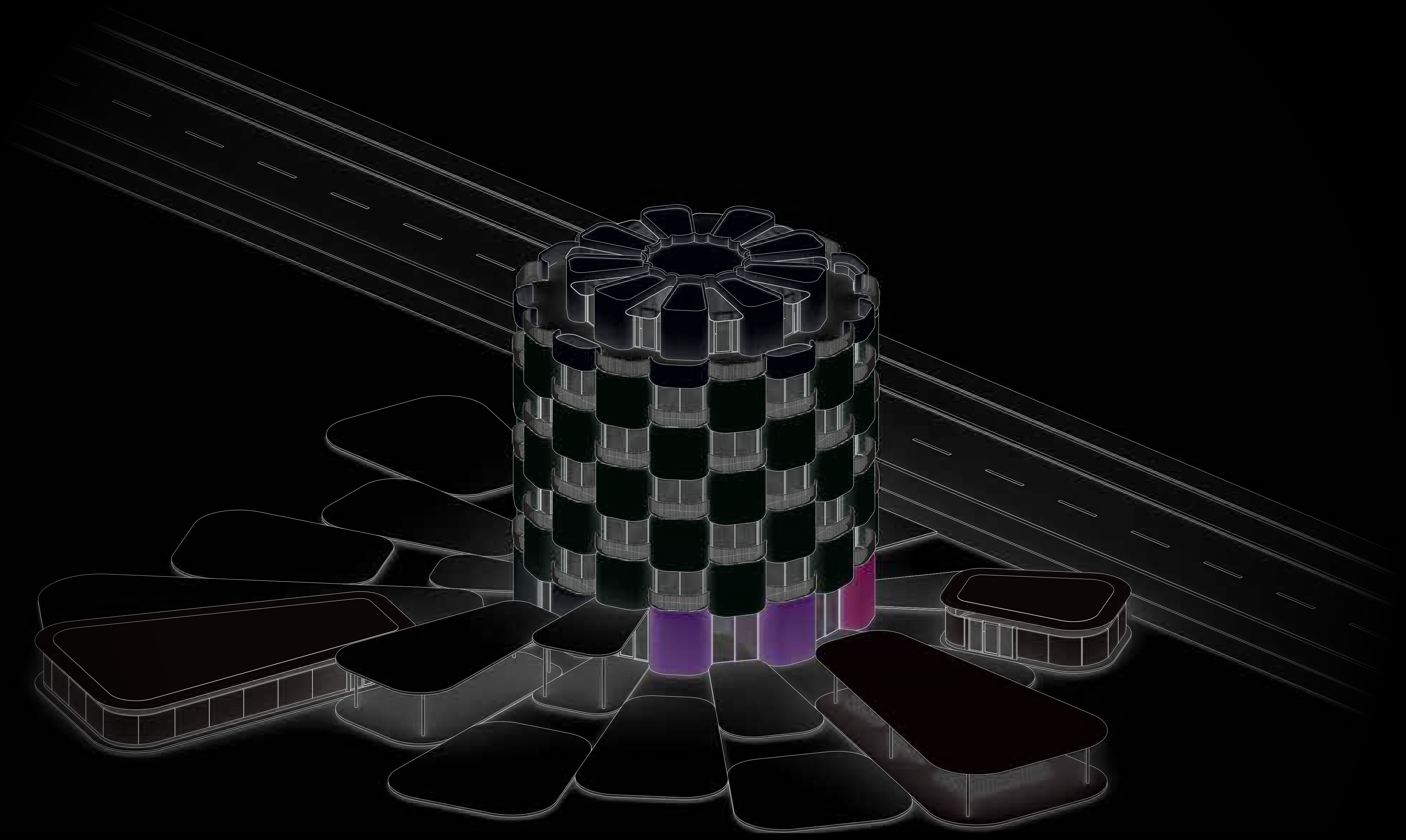


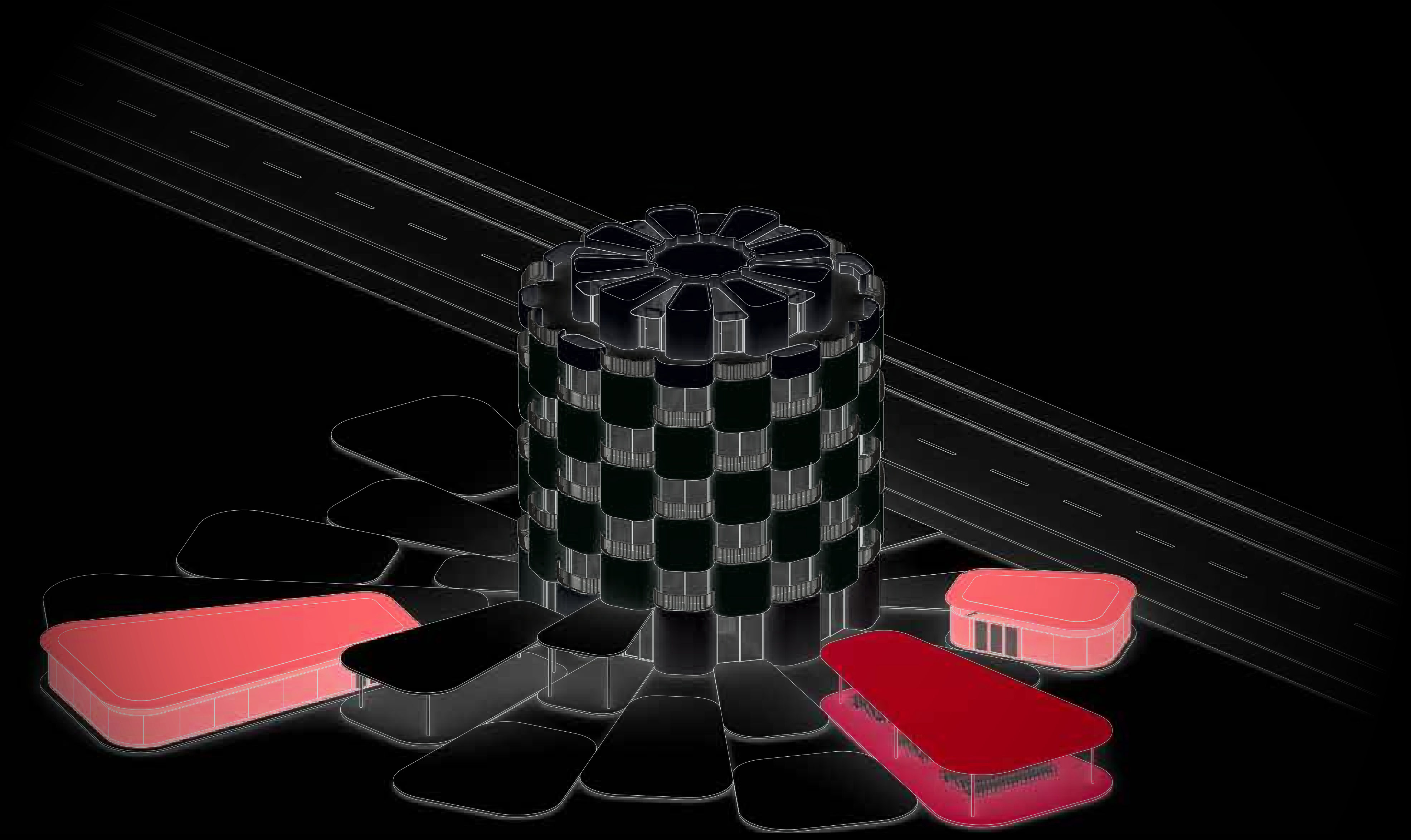

95%
5%
Regolar Units 57
26sqm each
Accessible Units 3
26sqm each - Located on GF

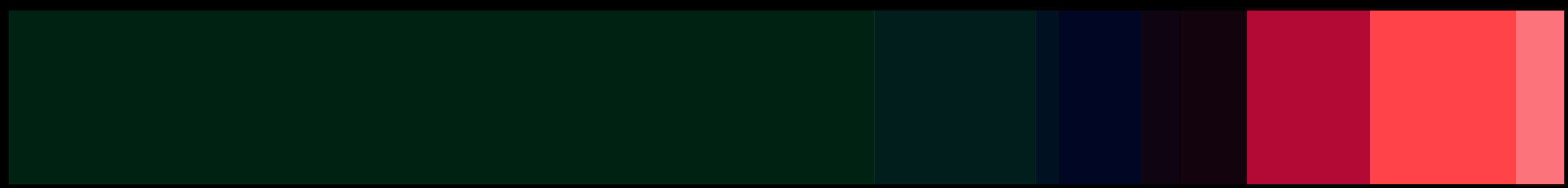



Mail Room
15 sqm
Shared Room
136 sqm
Laundry Room
Terrace
Green House
Study Room
Meeting Space
Kitchenette

PROGRAM DISTRIBUTION







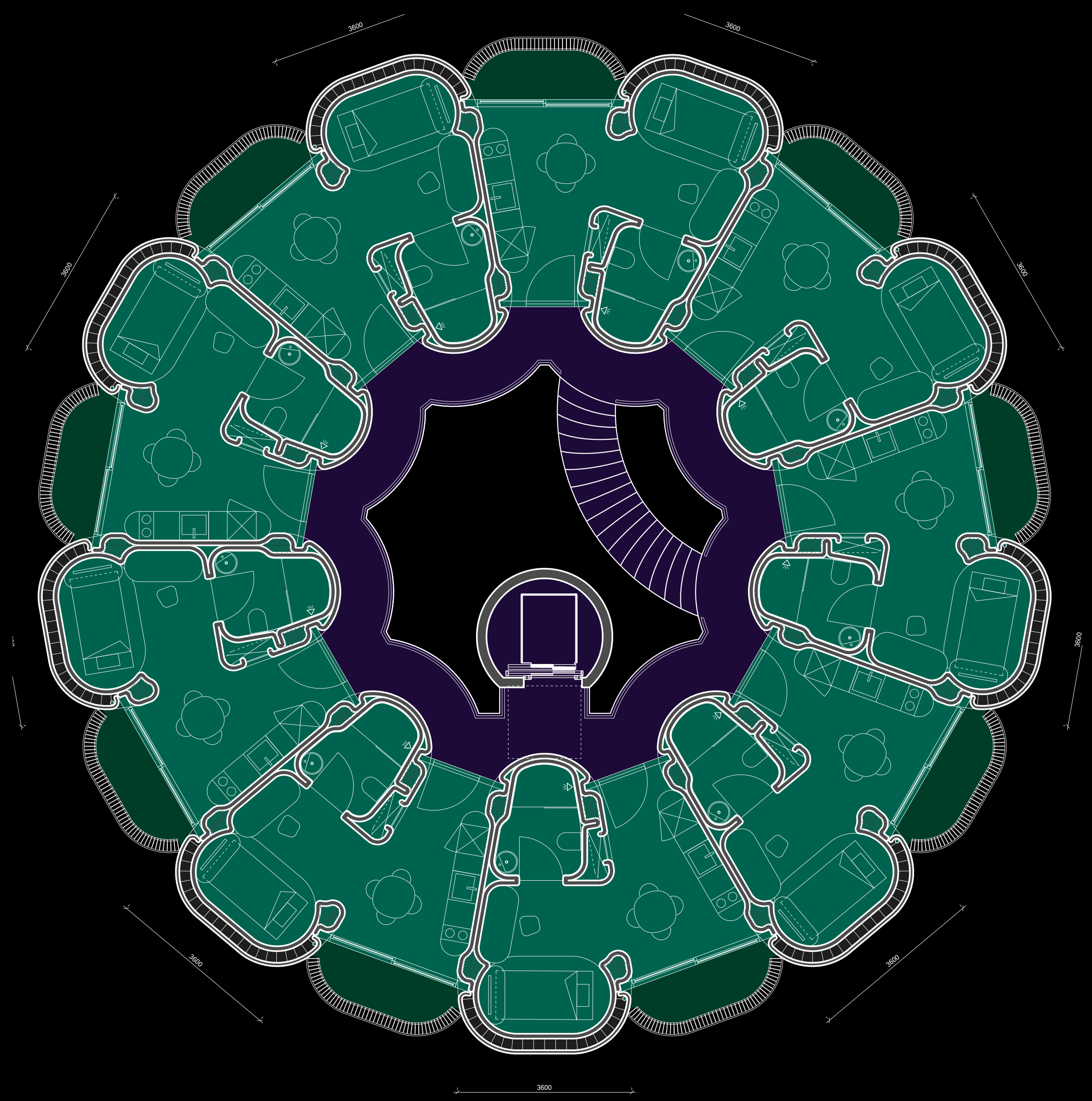
Bike Parking
177sqm
4 regular x 100 m2 **86 Spots**
1 cargo x 500 m2 **4 Spots**

Depot
211sqm
1 Storage unit per apartment
1,5mx1m **64 Units**

Garbage Room
70sqm
Adjacent to access road

AREA m²							UNIT COUNT	EFFICIENCY
FLOOR	UNIT	OUTDOOR	CIRCULATION	COMMON	COMMERCIAL	GFA		
GF	82,94		52,79	15,28	153,09	304,1	3	17,36%
F01	233,48	24,78	70,71			328,97	9	23,25%
F02	233,48	24,78	70,71			328,97	9	23,25%
F03	233,48	24,78	70,71			328,97	9	23,25%
F04	233,48	24,78	70,71			328,97	9	23,25%
F05	233,48	24,78	70,71			328,97	9	23,25%
F06	233,48	24,78	70,71			328,97	9	23,25%
F07		167,74	24,62	136,6		328,96	0	15,27%
TOTAL	1483,82	316,42	501,67	151,88	153,09	2606,88	57	21,90%

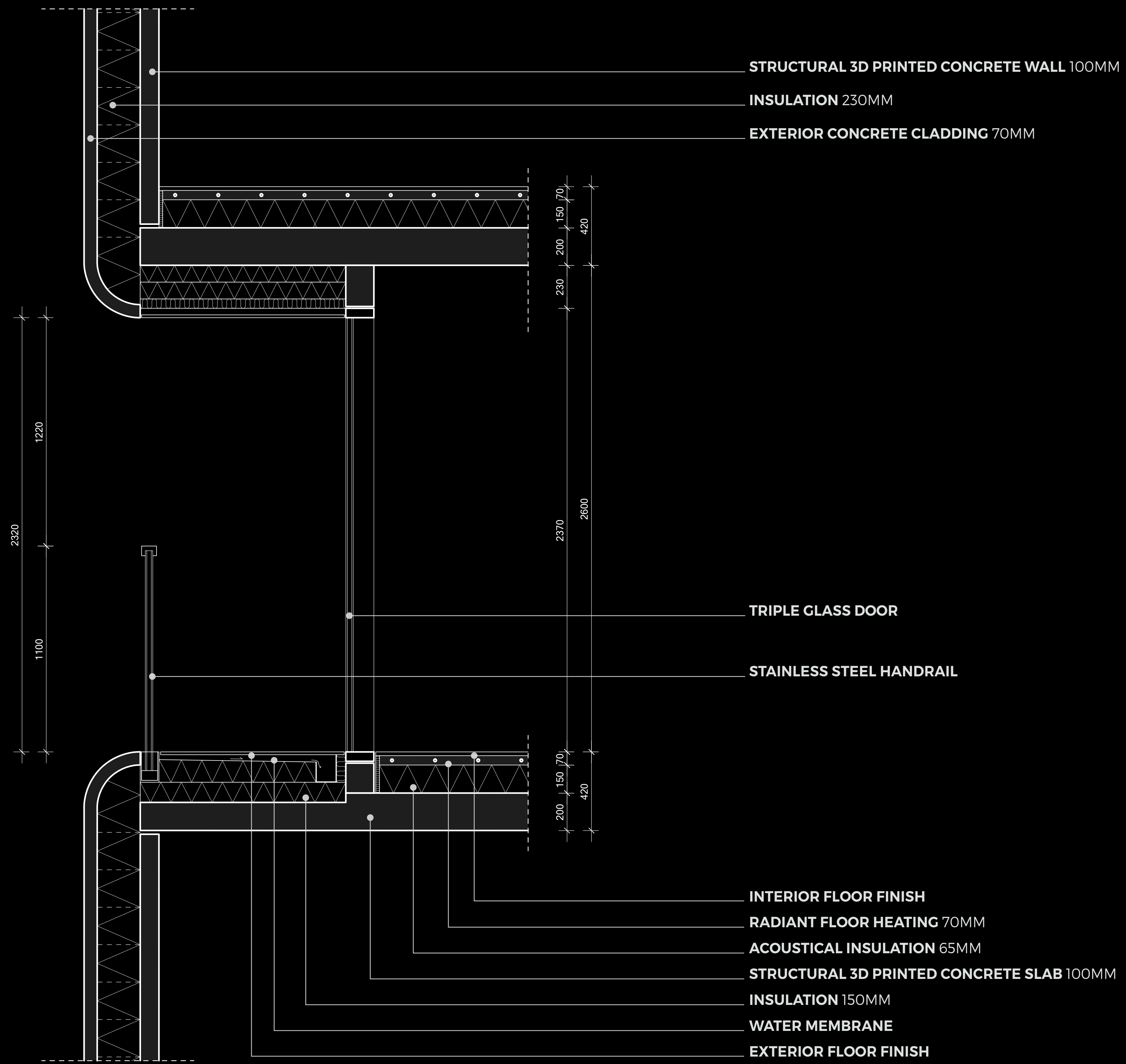
BIKE PARKING	177,4	m²
DEPOT	211,5	m²
GARBAGE ROOM	70	m²
Total	458,9	m²

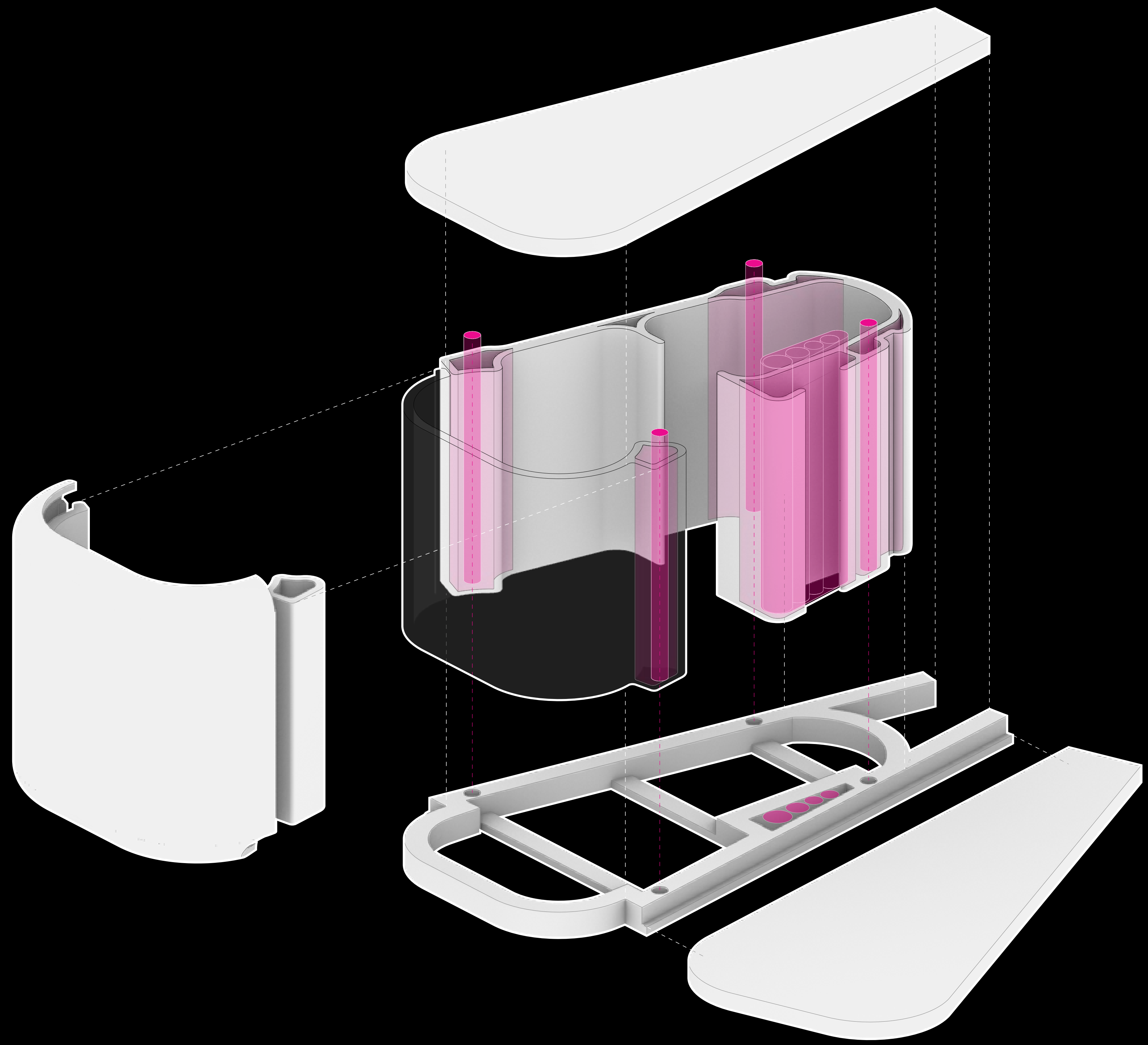


AREA m²							UNIT COUNT	EFFICIENCY
FLOOR	UNIT	OUTDOOR	CIRCULATION	COMMON	COMMERCIAL	GFA		
GF	82,94		52,79	15,28	153,09	304,1	3	17,36%
F01	233,48	24,78	45,85			304,11	9	16,41%
F02	233,48	24,78	45,85			304,11	9	16,41%
F03	233,48	24,78	45,85			304,11	9	16,41%
F04	233,48	24,78	45,85			304,11	9	16,41%
F05	233,48	24,78	45,85			304,11	9	16,41%
F06	233,48	24,78	45,85			304,11	9	16,41%
F07		167,74	24,62	136,6		328,96	0	15,27%
TOTAL	1483,82	316,42	352,51	151,88	153,09	2457,72	57	16,46%

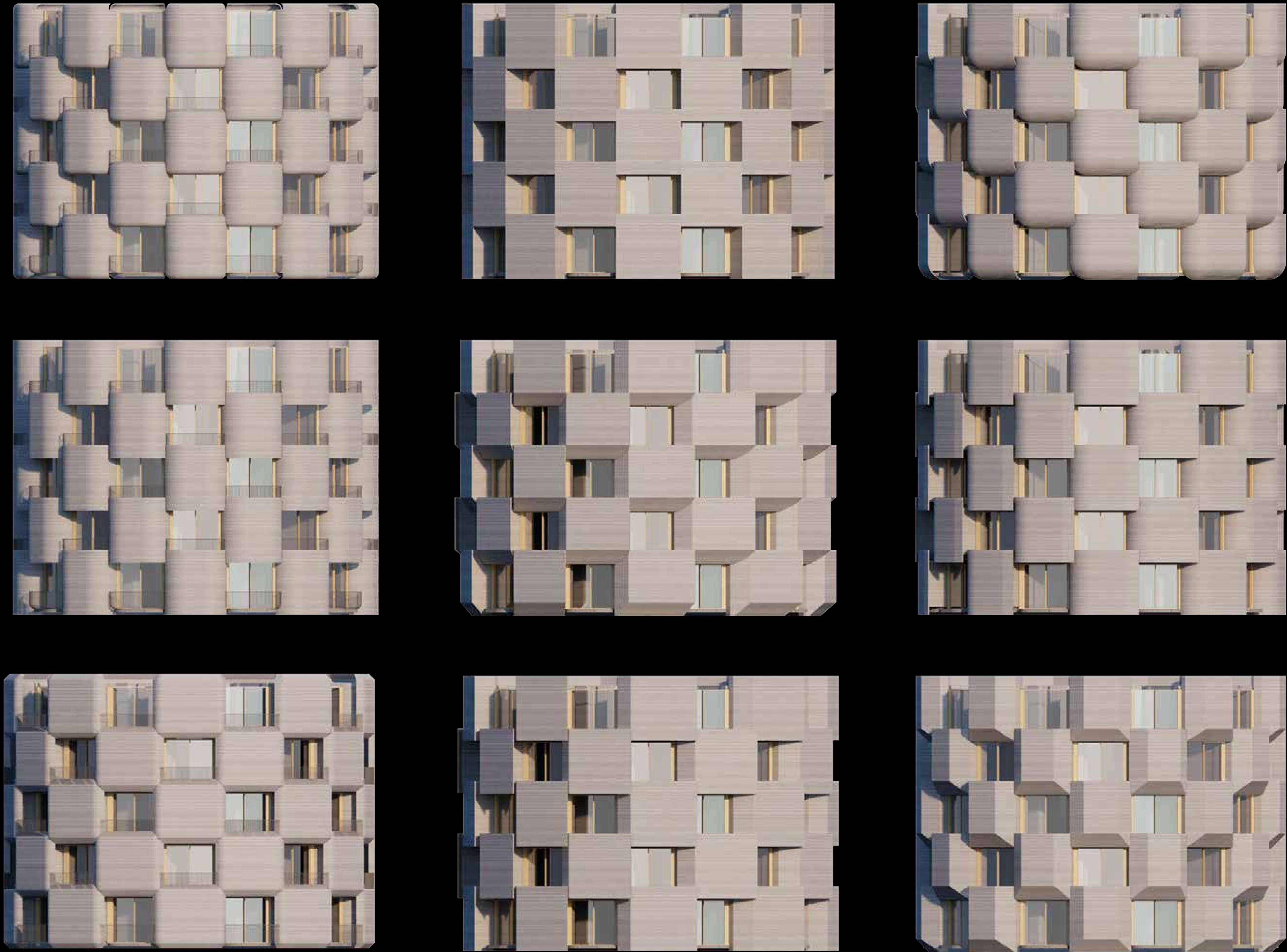
BIKE PARKING	177,4	m²
DEPOT	211,5	m²
GARBAGE ROOM	70	m²
Total	458,9	m²

DETAILED SECTION





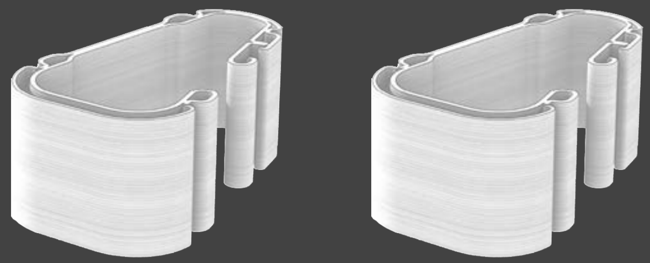
FACADE STUDIES



07

PROCESS S SUSTAINABILITY

EMBEDDED CO_2
Low clinker and alternative binders
Recycled materials



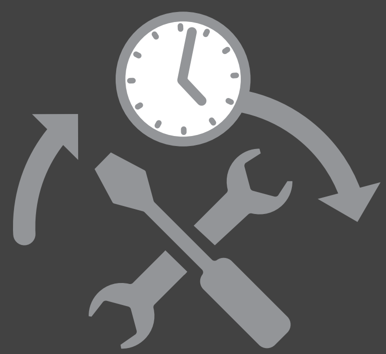
X

UNIT VOLUME
Paste volume reduction

TOTAL VOLUME
Structurally informed shapes
Reduced waste
Reusability

GLOBAL WARMING POTENTIAL (GWP) =

https://www.sciencedirect.com/science/article/pii/S0008884622001284



DURABILITY
Design for reuse

PARAMETERS THAT INFLUENCE THE GLOBAL WARMING POTENTIAL OF CONCRETE

A COMPARISON OF PRECAST CONCRETE AND 3D PRINTED CONCRETE

The Global Warming Potential of precast concrete

VS

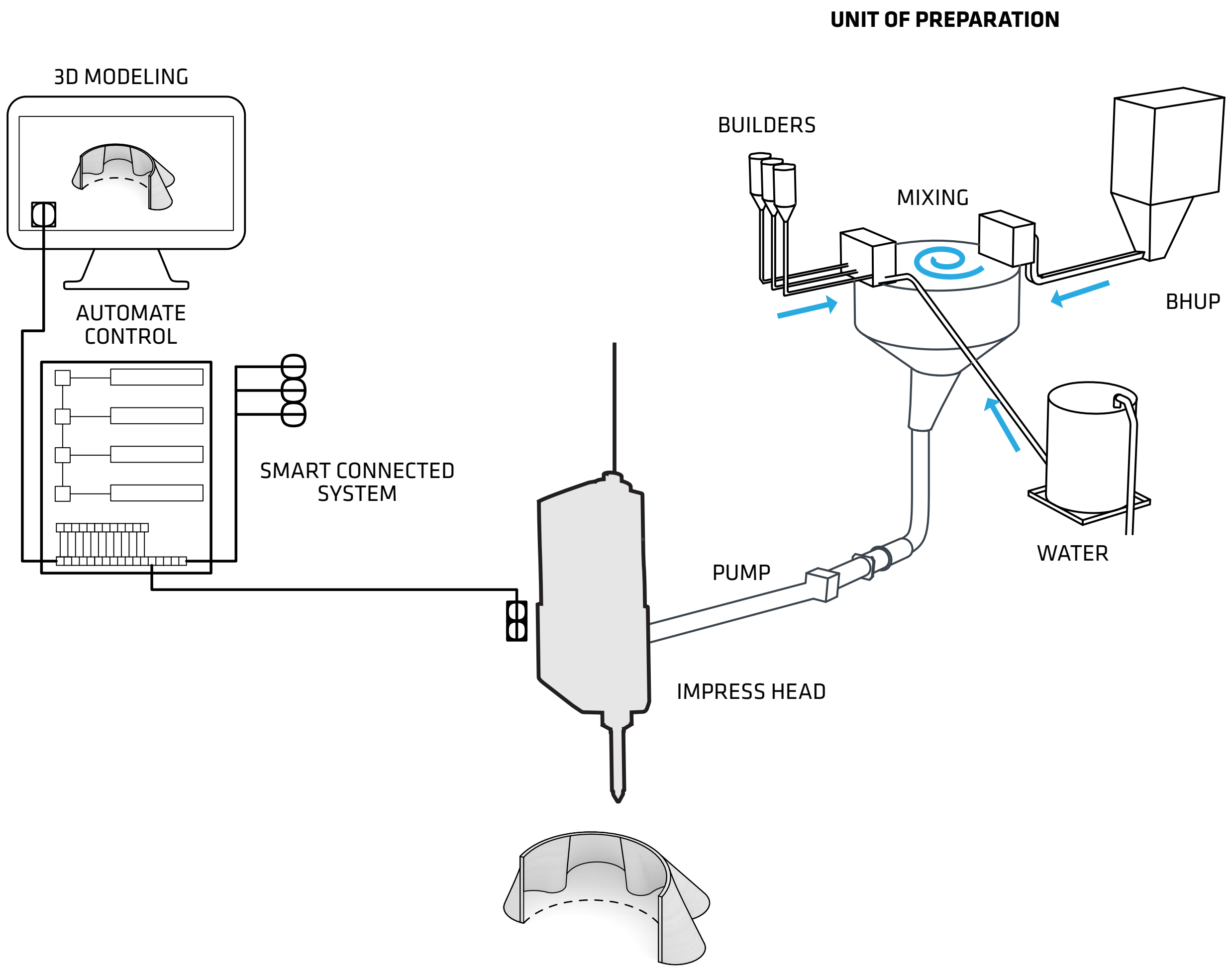
The Global Warming Potential of 3D printed concrete using a robotic arm

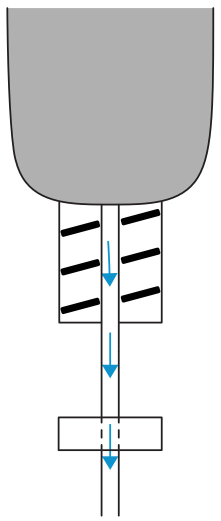
VS

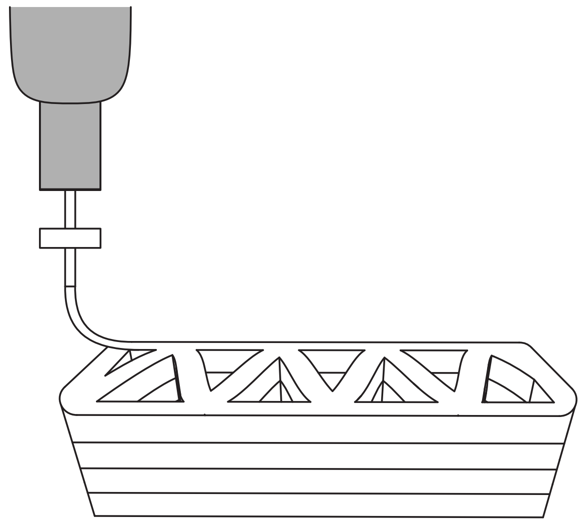
The Global Warming Potential of 3D printed concrete using a gantry

At the precast concrete plant, the mixed concrete is poured into forms via bucket conveyors and concrete distributors. It is then heat treated for a few hours for better hardening and left for an additional 12 to 18 hours in a storage area for curing before the precast concrete elements are ready to be transported to the construction site (1).

PRECAST CONCRETE PROCESS







CONCRETE 3D PRINTING PROCESS

Table 1. Hourly Embodied Impacts of the case-study robotic Printing cells. These include the robotic arm, the stirring/pumping/feeding device and the command system.

Impact category	Unit	Hourly Embodied Impacts of the Printing Cell based on ABB 8700	Hourly Embodied Impacts of the Printing Cell based on ABB 8700
agricultural land occupation	m^2*a / hour	4,4E-01	4,3E-01
climate change	**kg CO_2-Eq / hour**	**2,0E+00**	**1,8E+00**

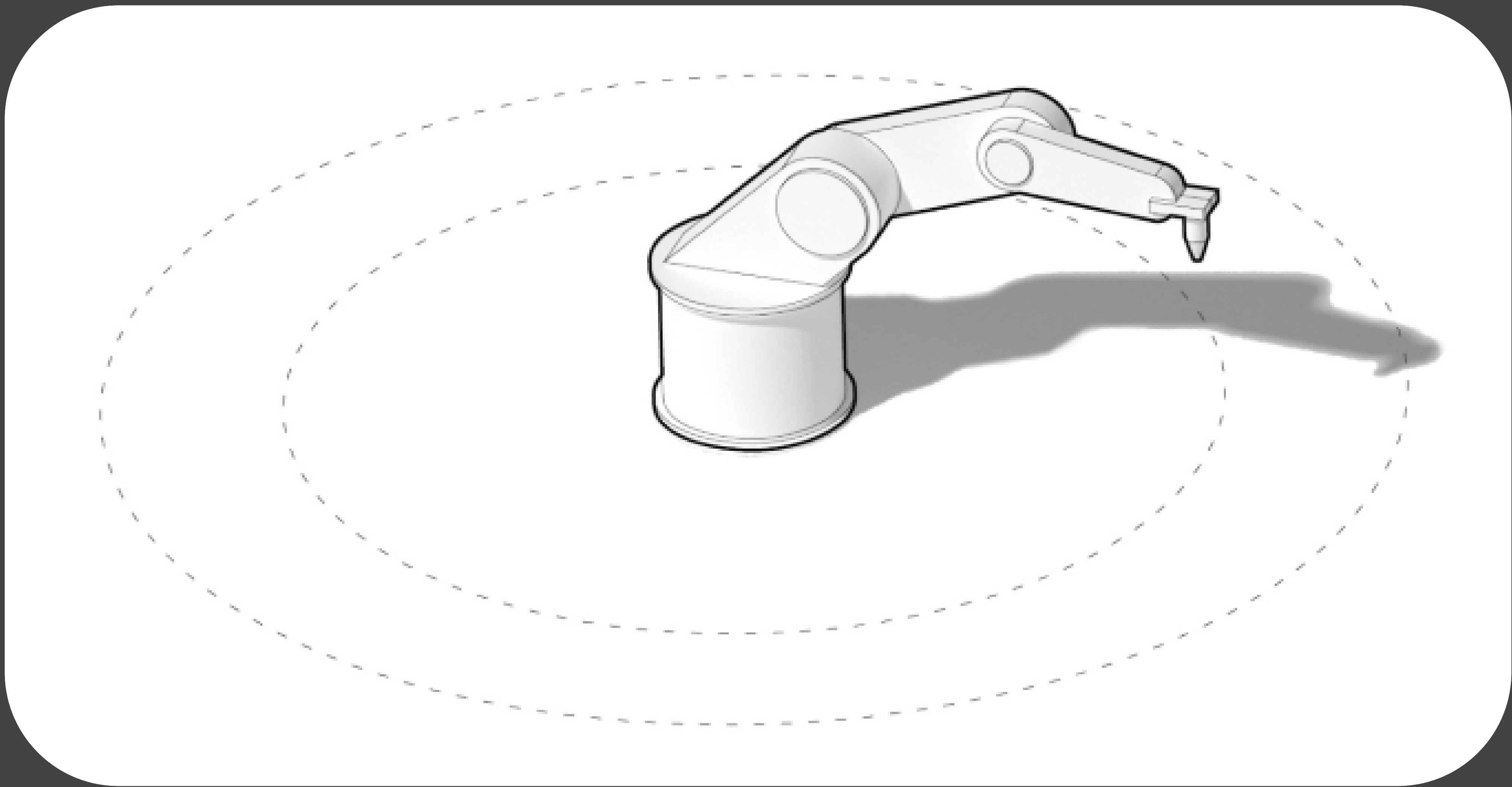
Table 3. Hourly Operational Impacts of the case-study robotic Printing cells. These include the robotic arm, the stirring/pumping/feeding device and the command system.

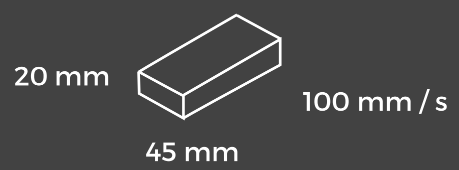
Impact category	Unit	Hourly Operational Impacts of the Printing Cell based on ABB 8700	Hourly Operational Impacts of the Printing Cell based on ABB 6620
agricultural land occupation	m^2*a / hour	6.20E-02	5.95E-02
climate change	**kg CO_2-Eq / hour**	**2.50E+00**	**2.40E+00**

The operational impact is calculated based on data from PhD "Cement and concrete research: Environmental impact of extrusion-based additive manufacturing - generic model, power measurements and influence of printing resolution"(1). The research paper quantifies the climate change as GWP pr hour (see table 3 and 4). The data is representative for a robotic arm and uses an average of two robotic arm printers; the ABB 8700 and AB 6620 (2).
The paper uses an estimated lifespan of 30.000 hours = 3,4 years for the 3D printing equipment. The paper also presents four settings for a robotic arm varying the printing speed and thickness (3).

This study uses the wall dimensions specified in BIG'S N3XTCON building design and the PhD data to compare the operational impact for printing 1 m^3 of concrete.

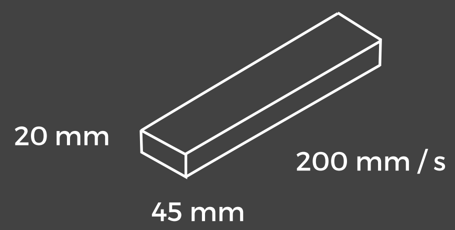
DATA BACKGROUND FOR 3D PRINTING PROCESSES WITH ROBOTIC ARM





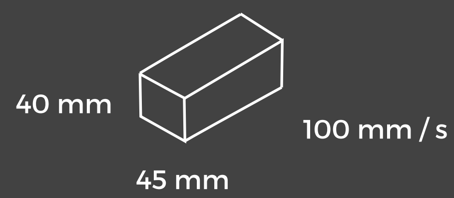
Setting 1: 1 m3 concrete / 185 min

13 kg CO2 eq / m3 concrete



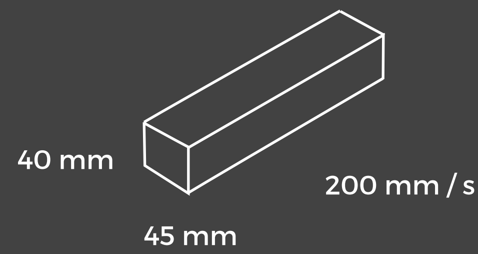
Setting 2: 1 m3 concrete / 93 min

7 kg CO2 eq / m3 concrete



Setting 3: 1 m3 concrete / 93 min

7 kg CO2 eq / m3 concrete



Setting 4: 1 m3 concrete / 46 min ✓

3 kg CO2 eq / m3 concrete

Printing fast uses more energy, but the robot has to run for a shorter period of time
- resulting in the lowest carbon emissions!

GWP ACCORDING TO DIFFERENT PRINTING VELOCITIES

VS

GWP OF PRECAST CONCRETE

Generic, C20/25, precast concrete representative for Europe (1)

291 kg CO2 eq / m3 concrete

Generic, C45/55, precast concrete representative for Europe (1)

354 kg CO2 eq / m3 concrete

GWP OF 3D PRINTED CONCRETE USING A ROBOTIC ARM

Generic C20/25, printed with 40 mm thickness and 200 mm/s (1) ✓

264 kg CO2 eq / m3 concrete

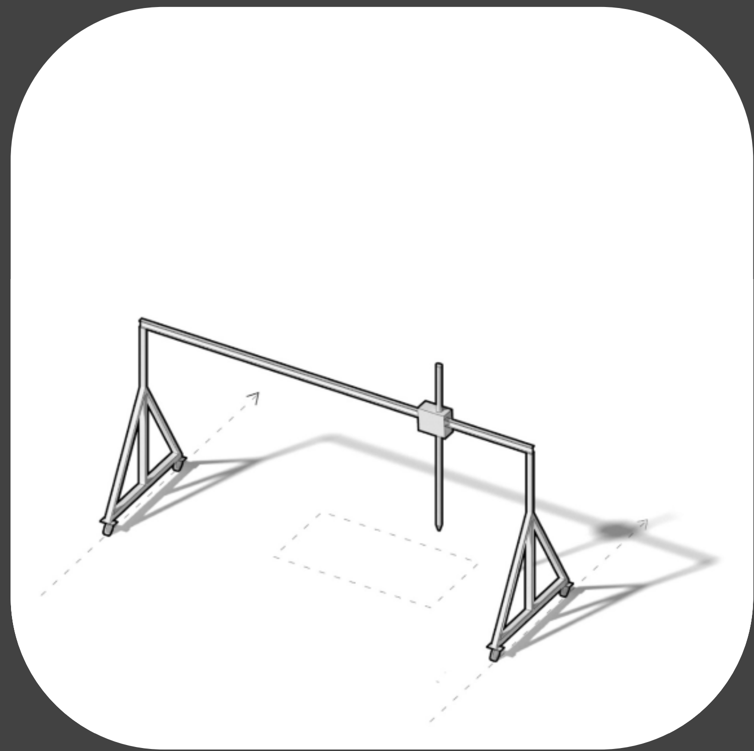
Generic C45/55, printed with 40 mm thickness and 200 mm/s (1) ✓

327 kg CO2 eq / m3 concrete

Given the same amount of reinforcement, the Global Warming Potential of precast concrete is compared to that of 3D printed concrete using a robotic arm.

GWP OF PRECAST CONCRETE VS 3D PRINTED CONCRETE USING A ROBOTIC ARM

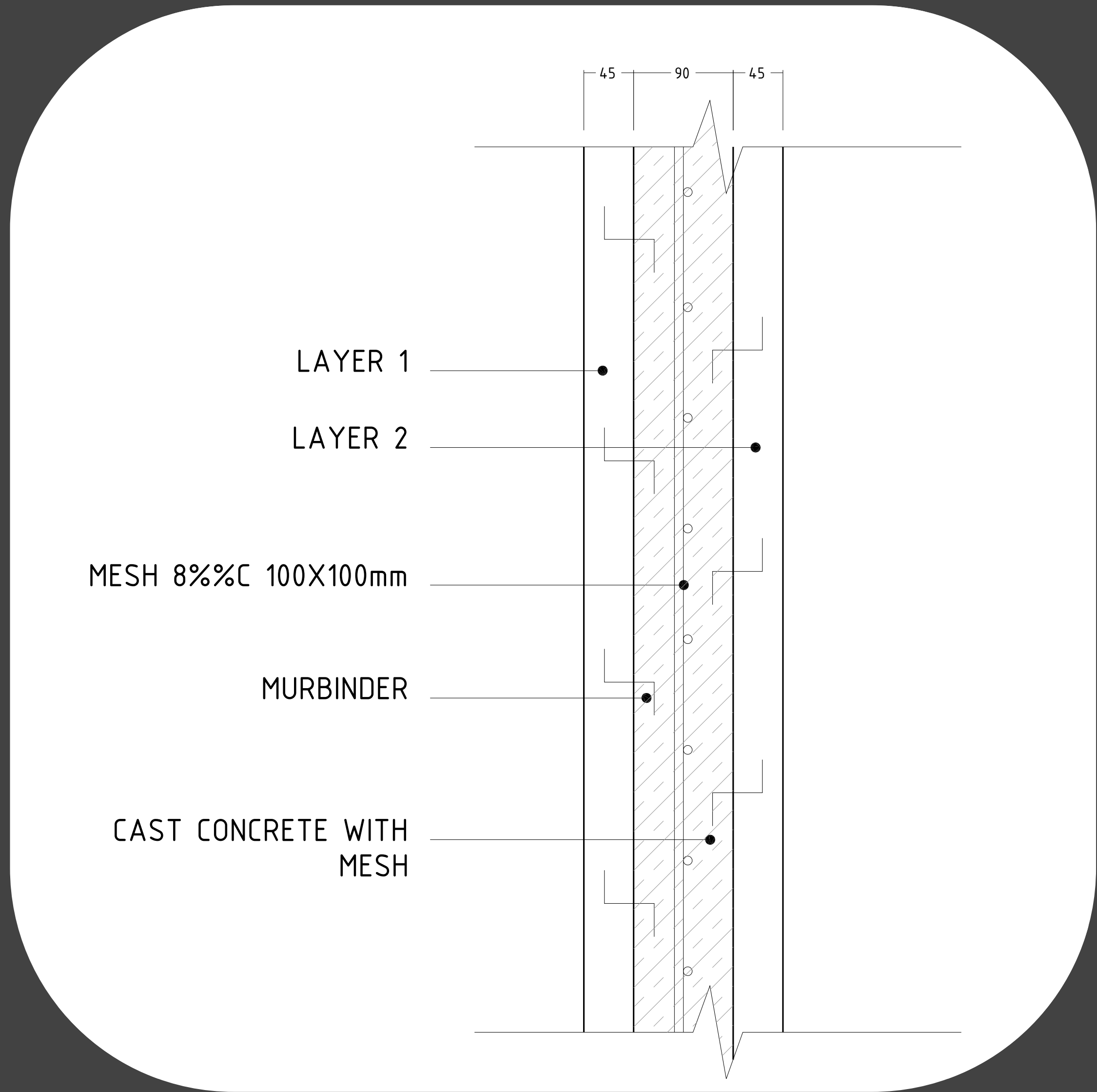
SINGLE ROBOTIC
ARM PRINTER



GANTRY CRANE
ROBOTIC PRINTER

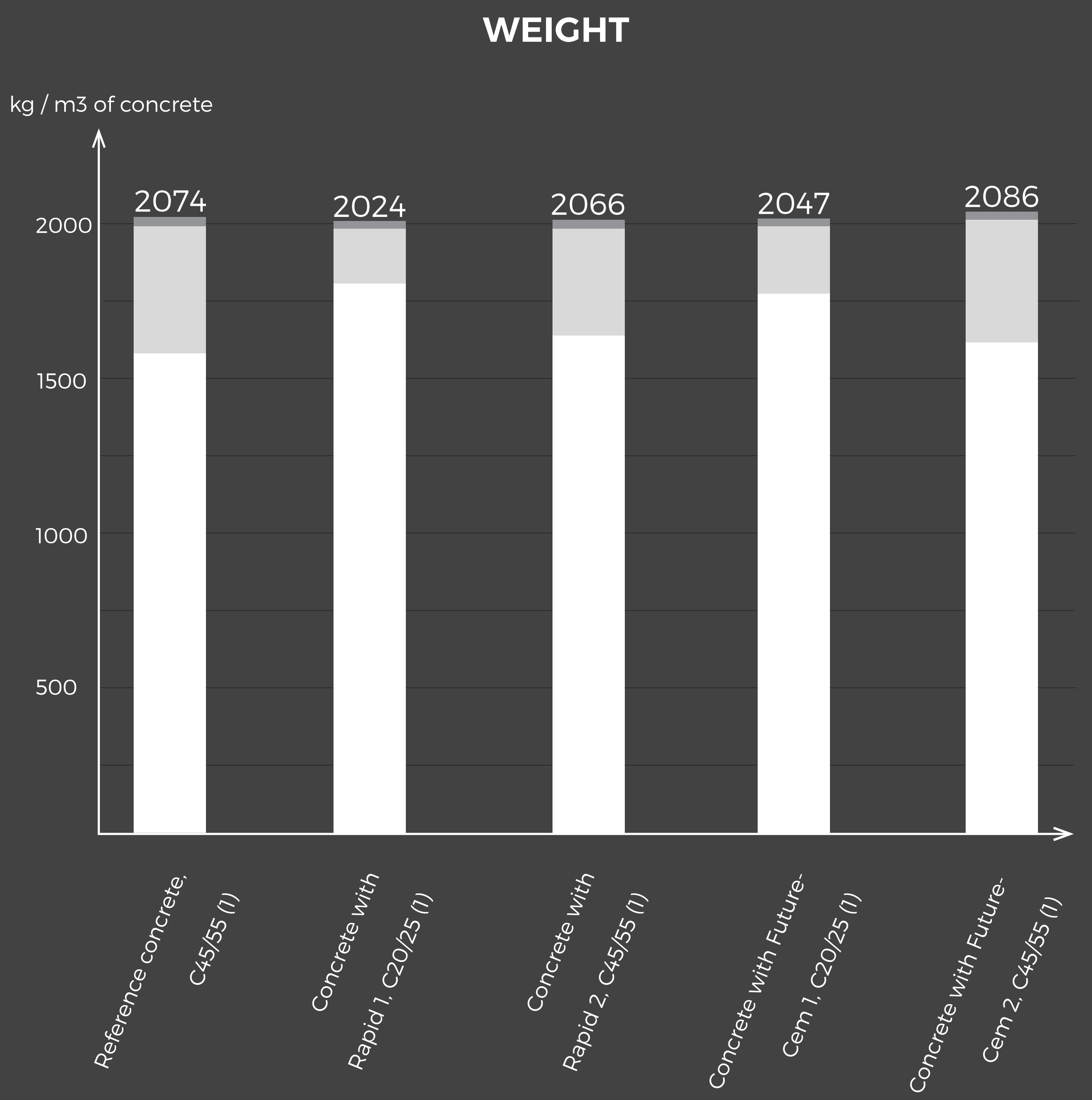
We would like to compare the operational impact from the robotic arm with a gantry of the brand **COBOD**, since this one is likely to be used for N3XTCON!

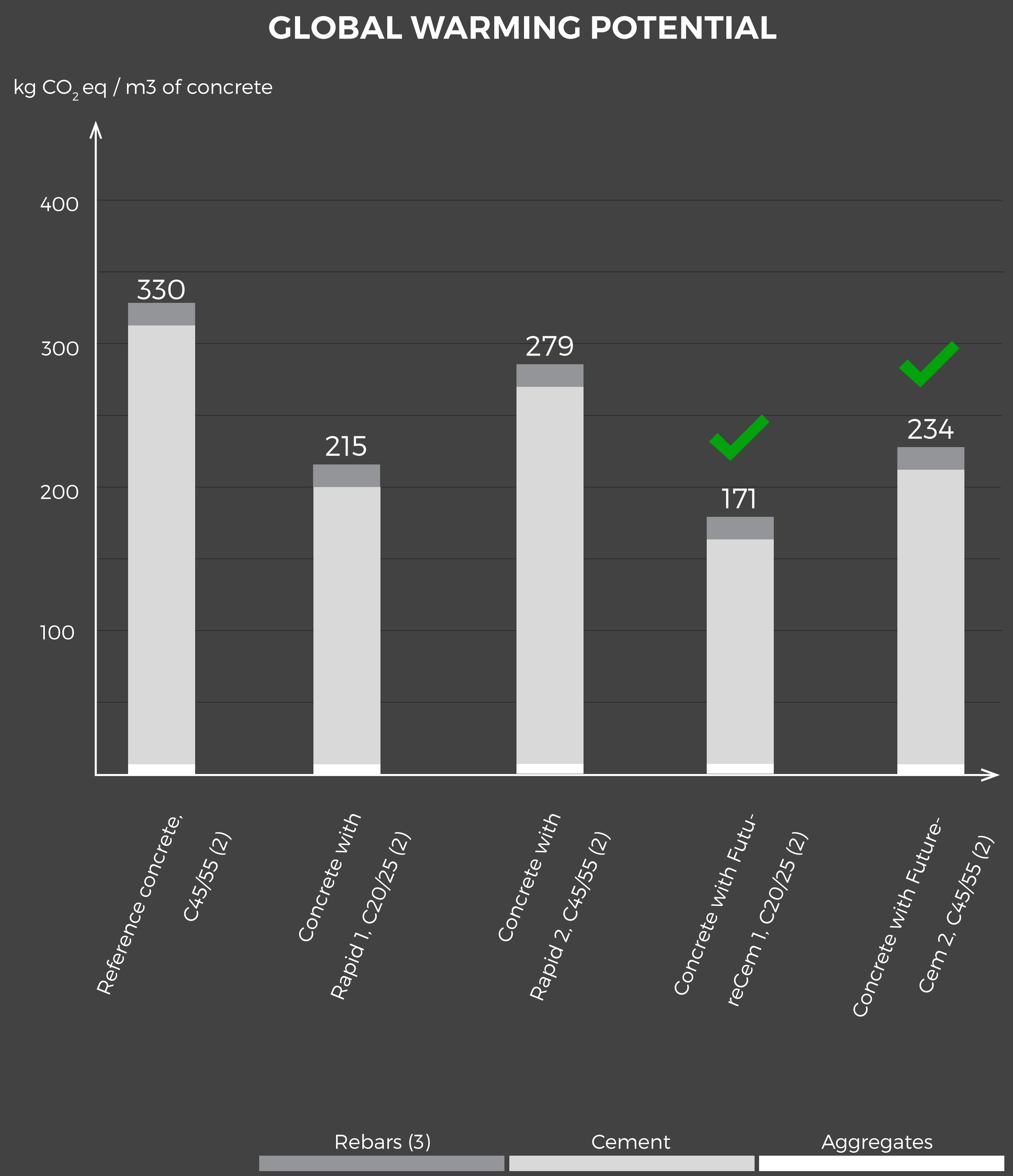
COMPARISON OF ROBOTIC ARMS AND GANTRIES



4 types of insulation are being considered for the cavities inside the walls: light weight concrete, EPS, blown-in cellulose fibre insulation from recycled paper, and blown-in wood fibre insulation. A wall section is composed of two layers of 3D printed concrete, each 45 mm wide and a cavity of 90 mm for insulation

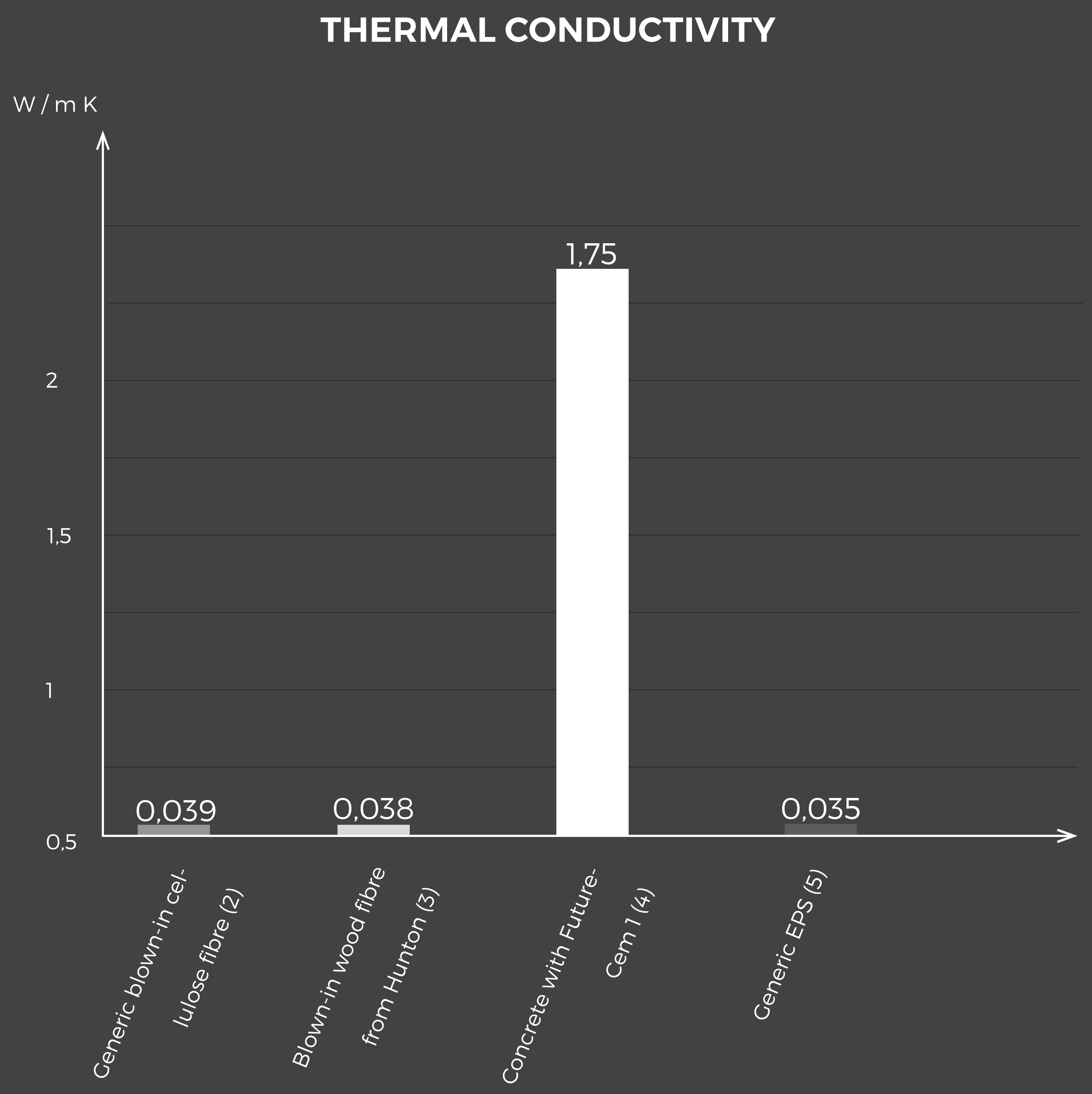
WALL BUILT UP FOR N3XTCON

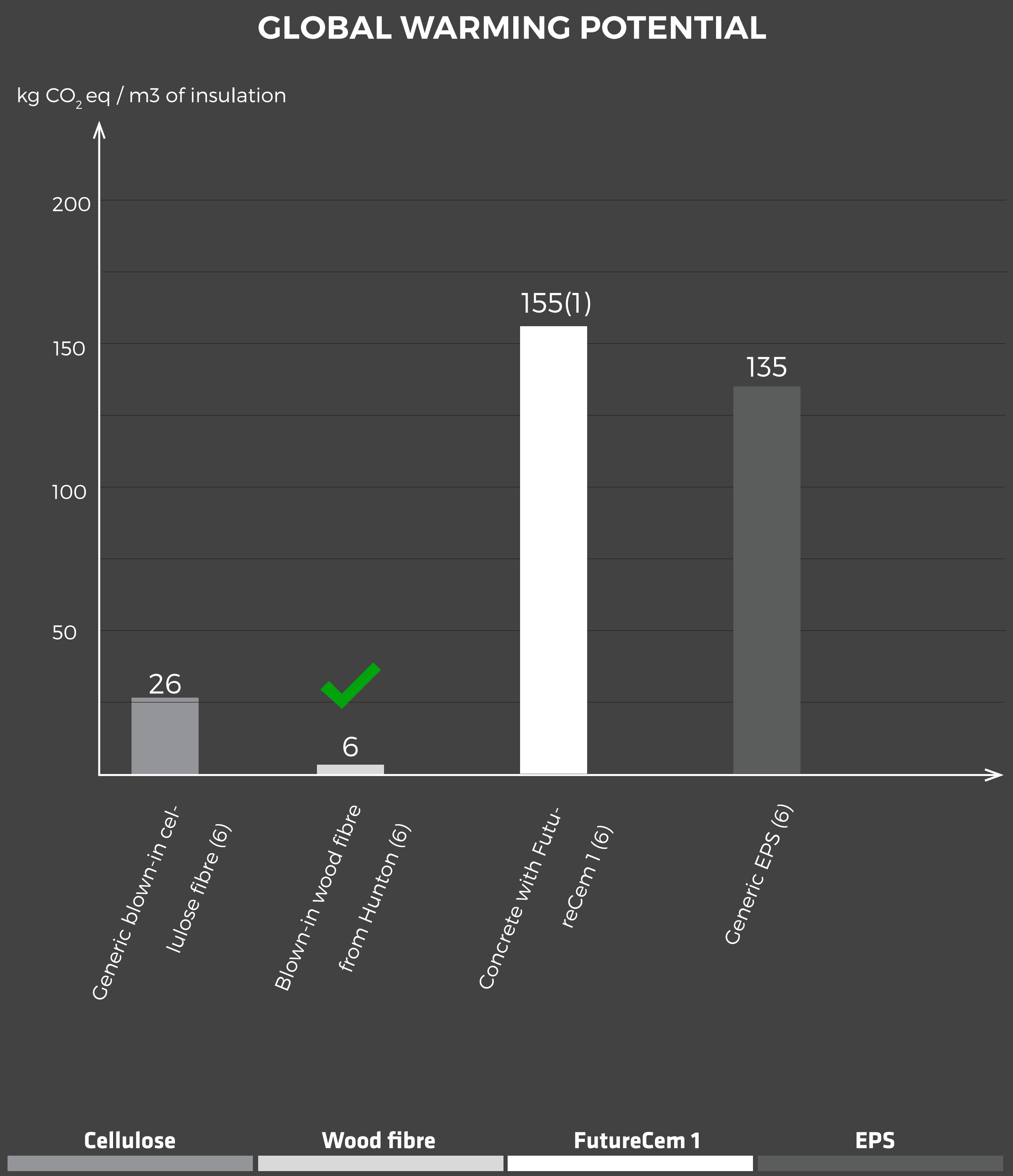




The aggregates weigh the most, but the cement is the biggest contributer to the GWP!
Concrete with FutureCem has the lowest GWP.

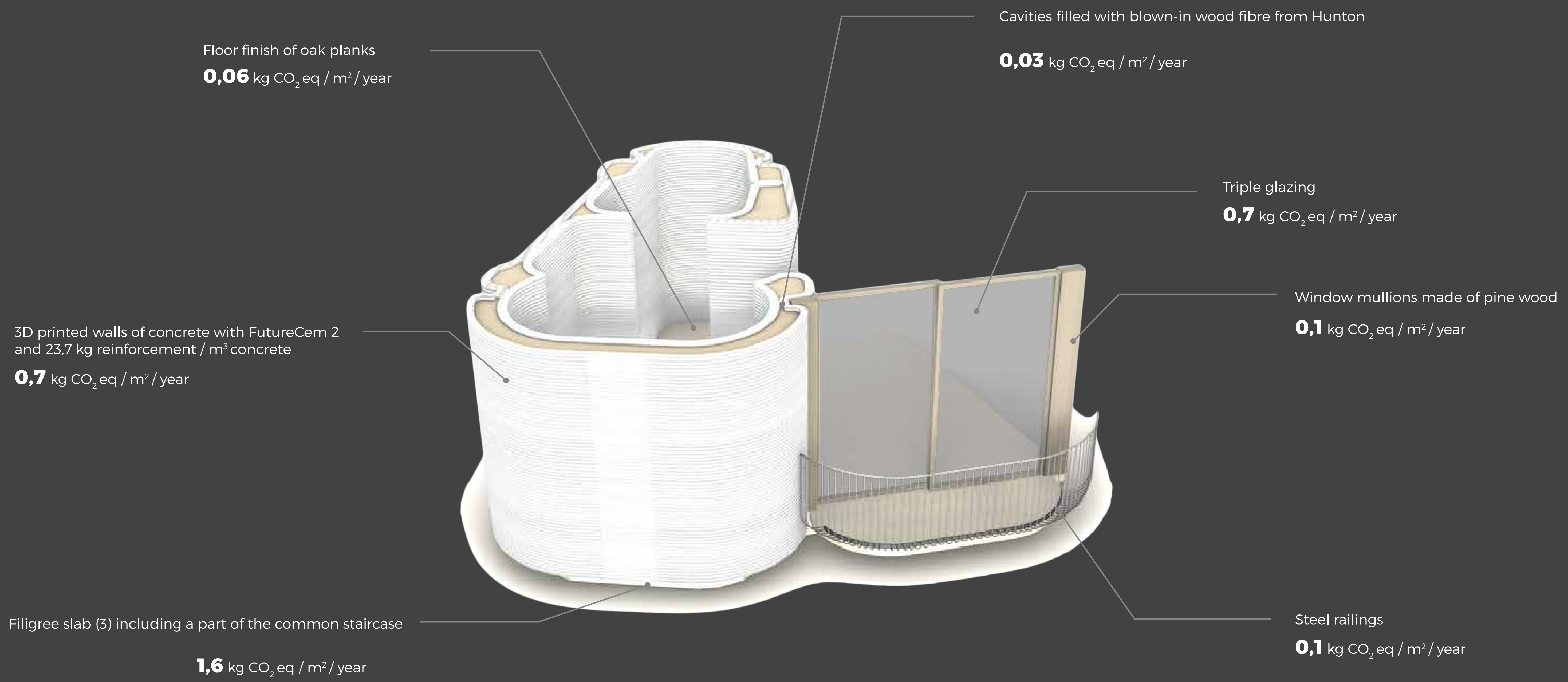
COMPARING THE GWP OF DIFFERENT CONCRETE TYPES





A high thermal conductivity means low insulation quality.

COMPARING THE GWP OF DIFFERENT INSULATION TYPES



3,4 kg CO_2 eq / m² / year*

* This study is only considering the embodied energy of the N3XTCON precast project in concept stage. The analysis uses a reference life span of 50 years and and the floor area is 31,8 m2 taking part of the shared hall way and stair case into account.

THE GWP OF ONE UNIT - USING MATERIALS WITH THE **LOWEST** CARBON FOOTPRINT

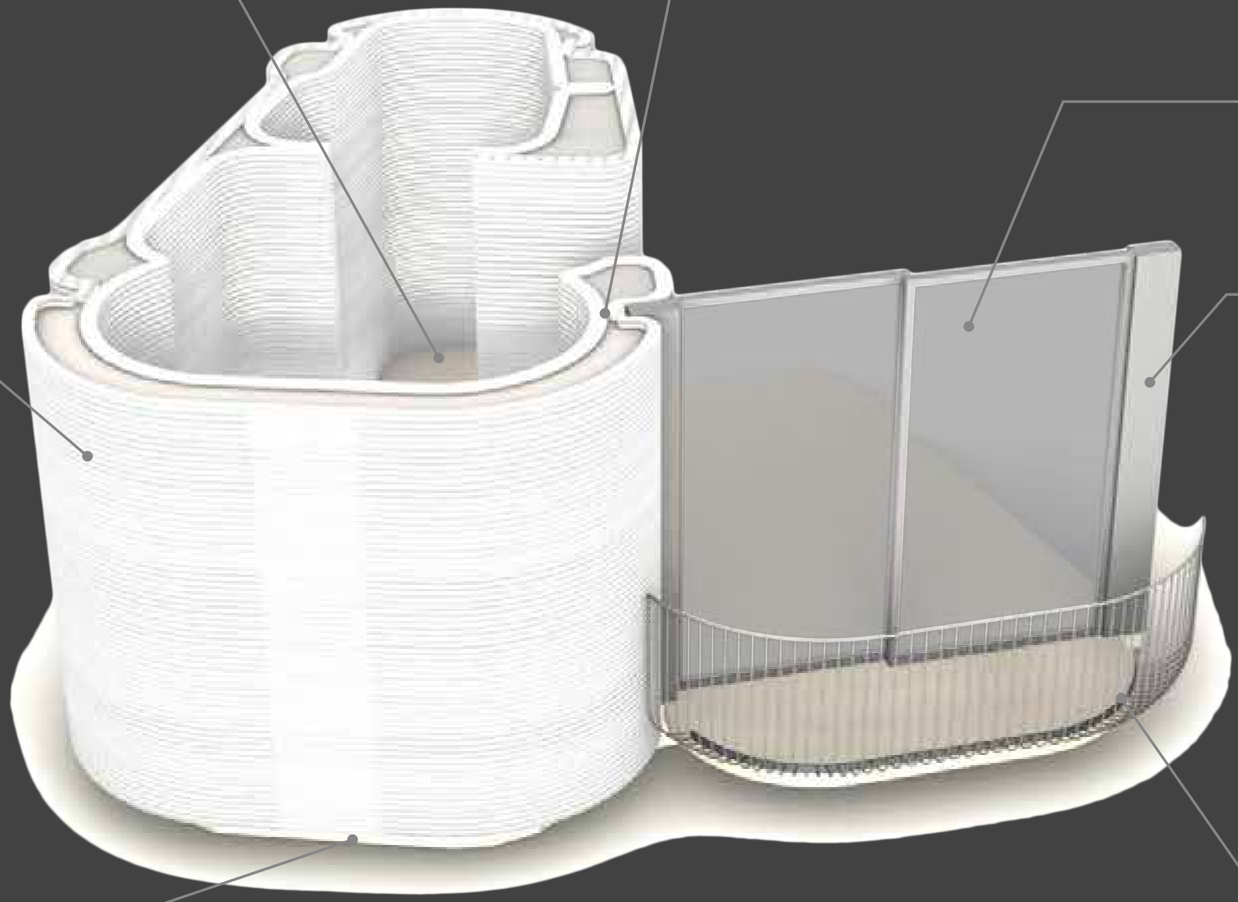
Floor finish of oak planks
0,06 kg CO_2 eq / m² / year

Exterior wall cavity filled with EPS and the rest of the walls filled with FutureCem 1 concrete (6)
0,8 kg CO_2 eq / m² / year ↑ 2353%

Triple glazing
0,7 kg CO_2 eq / m² / year

Window mullions made of aluminium
1,9 kg CO_2 eq / m² / year ↑ 1454%

Generic precast concrete and 23,7 kg reinforcement / m³ concrete
1,3 kg CO_2 eq / m² / year ↑ 81%



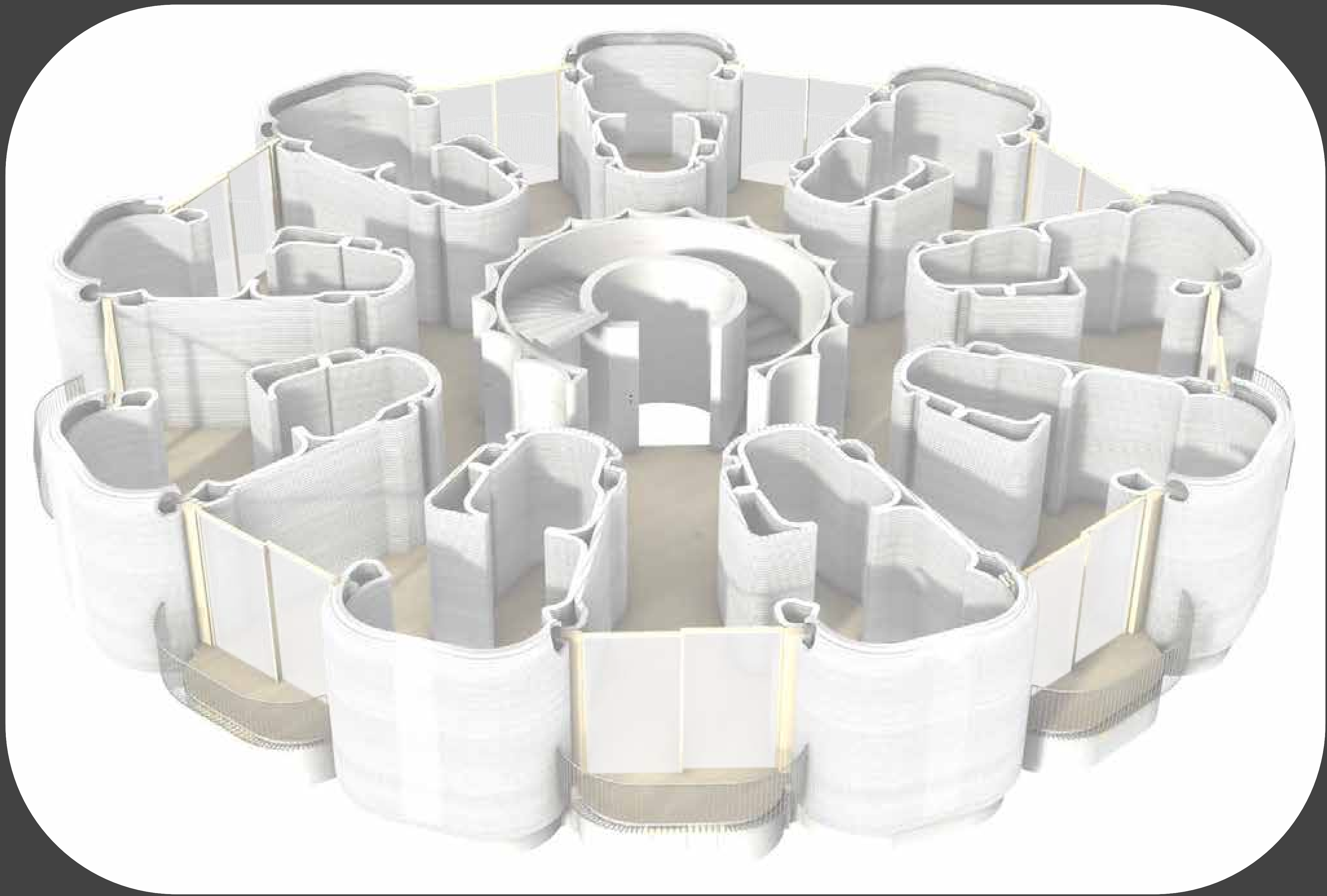
Filigree slab (3) including a part of the common staircase
1,6 kg CO_2 eq / m² / year

Steel railings
0,1 kg CO_2 eq / m² / year

6,5 kg CO2 eq / m² / year* ↑ 90%

* This study is only considering the embodied energy of the N3XTCON precast project in concept stage. The analysis uses a reference life span of 50 years and and the floor area is 31,8 m2 taking part of the shared hall way and stair case into account.

THE GWP OF ONE UNIT - USING MATERIALS WITH THE **HIGHEST** CARBON FOOTPRINT



48510 kg CO_2 eq / floor plate*

3,4 kg CO_2 eq / m² / year

* This study is only considering the embodied energy of the N3XTCON precast project in concept stage. The analysis uses a reference life span of 50 years and and the floor area is 287 m2.

THE GWP OF ONE FLOOR PLATE - USING MATERIALS WITH THE **LOWEST** CARBON FOOTPRINT

CONCRETE WALLS

Quantities for one unit
4,9 m^3 concrete with FutureCem 2

Quantities for one floor plate
44 m^3 concrete with FutureCem 2

Assumptions
This study uses concrete with FutureCem 2 for the 3D printed walls. The ingredients ratio and specified aggregates are provided by the Danish Technological Institute (1).
The footprint of one unit is 1,83 m2 and the height is 2,67 m. The concrete "pockets" around the reinforcement is assumed to be 200 mm x 300 mm.

Life cycle stages included
A1-A3, A4, C3 and D

Reference life span
60 years

REINFORCEMENT IN WALLS

Quantities for one unit
116 kg of steel

Quantities for one floor plate
1043 kg of steel

Assumptions
The amount of reinforcement is based on the assumption of 2 rebars of 12 mm diameter C-C 1000 mm. Additional 8 mm horisontal rebar every 300 mm. 23,7 kg reinforcement / m^3 concrete.

Life cycle stages included
A1-A3, C4 and D

Reference life span
80 years

INSULATION

Quantities for one unit
8,9 m^3 of insulation

Quantities for one floor plate
79 m^3 of insulation

Assumptions
4 materials are being assessed for insulating the 3D printed walls: Concrete with FutureCem 1 (1), EPS (2), blown-in cellulose fibre insulation from recycled paper (3) and blown-in wood fibre insulation (4). Fire retarandts EPS: hydrogen bromide, Cellulose: boric acid and borax, Wood fibre: nitrogen and phosphor and ammonium sulfate. Fire resistance class for EPS, Cellulose and Wood fibre: Euroclass E.

Life cycle stages included
A1-A3, C4 and D

Reference life span
80 (EPS), 60 (concrete), 50 (cellulose fibre), 60 (wood fibre)

WINDOW

Quantities for one unit
9 m^2 of glass and 16,2 m mullions

Quantities for one floor plate
81 m^2 of glass and 146 m mullions

Assumptions
The windows are triple glazing and two different materials are being compared for the mullions: pine and aluminium.
The mullions are assumed to have a linear weight of 2,14 kg/m for the pine wood and 3 kg /m for the aluminium mullions.
The glazing consists of 3 glass panes each 4 mm thick and with a 16 mm distance.

Life cycle stages included
A1-A3, C3, C4 and D

Reference life span
20 (wood), 25 (glass)

LIST OF MATERIAL SPECIFICATIONS AND QUANTITIES FOR THE LIFE CYCLE ANALYSES

SLAB

Quantities for one unit
31,8 m2 of concrete

Quantities for one floor plate
287 m2 of concrete

Assumptions
The slab is a precast concrete filigree slab and the reinforcement is assumed to be 150 kg steel / m^3 of concrete (1). The slab is 80 mm thick.

Life cycle stages included
A1-A3, C3 and D

Reference life span
75 years

TOP FLOOR

Quantities for one unit
20 m2 of wood

Quantities for one floor plate
180 m2 of wood

Assumptions
The entire floor inside each unit is assumed to be covered with 20 mm planks of oak.

Life cycle stages included
A1-A3, C3 and D

Reference life span
60 years

PRECAST STAIRS AND ELEVATOR SHAFT

Quantities for one unit
2,8 m3 of concrete, C45/55

Quantities for one floor plate
25,4 m3 of concrete, C45/55

Assumptions
The central staircase and surrounding walls are included and the reinforcement is assumed to be 150 kg steel / m3 concrete for both stairs and elevator shaft.

Life cycle stages included
A1-A3, C4 and D

Reference life span
60 years

RAILINGS FOR THE BALCONY

Quantities for one unit
0,008 m3 of steel

Quantities for one floor plate
0,07 m3 of steel

Assumptions
The railings are made of steel and weigh 62 kg pr balcony.

Life cycle stages included
A1-A3, C4 and D

Reference life span
80 years

LIST OF MATERIAL SPECIFICATIONS AND QUANTITIES FOR THE LIFE CYCLE ANALYSES

08

THE MOCK UP

OFF-SITE 3D PRINTING OF MODULE

TESTING / ENGINEERING
(CODE AND EVALUATION)

3D PRINTERS
(TECHNOLOGY DEVELOPMENT)

CONCRETE
(MATERIAL PROVIDER)

INDUSTRY TRANSFORMATION
(3D PRINT USER)

ARCHITECTS
(FINDING APPLICATION)